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Modules 1-8

Learning Facilitator's Manual

Distance Learning

Alberta
EDUCATION

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Physics 20

LEARNING FACILITATOR'S MANUAL

Distance Learning

Alberta
EDUCATION

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Note

This Physics 20 Learning Facilitator's Manual contains answers to teacher-assessed assignments and the final test; therefore, it should be kept secure by the teacher. Students should not have access to these assignments or the final test until they are assigned in a supervised situation. The answers should be stored securely by the teacher at all times.

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This document is intended for	
Students	
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Administrators	
Parents	
General Public	
Other	

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Modules 1-8
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Teachers

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The Alberta Distance Learning Centre is dedicated to upgrading and continually improving your Learning Facilitator's Manual so that it accurately reflects any necessary revisions we have had to make in the student module booklets, assignment booklets, or the sample final test. The types of revisions that will be made are those that make the course more accurate, current, or more effective.

The ADLC will send you the **latest enhancements or minor upgrades** for your Learning Facilitator's Manual if you return the following registration card to: Alberta Distance Learning Centre, Box 4000, Barrhead, Alberta, T0G 2P0, Attention: Instructional Design and Development.

ADLC Learning Facilitator's Manual Registration Card

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You can help ensure that distance learning courseware is of top quality by letting us know of areas that need to be adjusted. Call the Alberta Distance Learning Centre free of charge by using the RITE line and ask for the Editing Unit. Also, a teacher questionnaire has been included at the back of most Learning Facilitator's Manuals. Please take a moment to fill this out.

We look forward to hearing from you!

Contents

Introduction 1

Overview of the Program of Studies 3

Overview of Physics 20 4

Structure of the Learning Package 5

Using This Learning Package in the Classroom 8

Evaluation 12

Introducing Students to the System 15

Module 1 17

Module 2 29

Module 3 42

Module 4 54

Module 5 60

Module 6 70

Module 7 79

Module 8 89

Answer Key to the Final Test 98

Student's Copy of Final Test

Teacher Questionnaire

Introduction

A survey of these course materials will confirm that this new learning package has been specially designed for many kinds of teachers working in a variety of situations.

Which Category Do You Fit?

- ☐ Small Schools Teacher
  - ☐ inexperienced
  - ☐ experienced, but in other subject areas
  - ☐ experienced in teaching Physics 20, but wanting to try a different approach
- ☐ Distance Learning Teacher
  - ☐ travelling to schools within the jurisdiction
  - ☐ using facsimile and teleconferences to teach students within the area
- ☐ Larger Schools Teacher
  - ☐ inexperienced
  - ☐ experienced in teaching Physics 20, but wanting to try a different approach

Because these materials have been created by experienced classroom teachers and distance learning specialists, they have many advantages for students and teachers regardless of their situations.

Advantages for Students

- incorporates a strong learner-centred philosophy
- promotes such qualities in the learner as autonomy, independence, and flexibility
- is developed through media which suit the needs and circumstances of the learner
- reflects the experiential background of Alberta students
- opens up opportunities by overcoming barriers that result from geographical location
- promotes individualized learning, allowing learners to work at their own pace

Advantages for Teachers

- allows teachers maximum teaching time and minimizes preparation time
- includes different routes through the materials to suit different learners
- incorporates a wide range of teaching strategies, in particular those using independent and individual learning
- delivers curriculum designed by education specialists that reflects the Alberta Education Program of Studies with an emphasis on Canadian content
- provides learning materials which are upwardly compatible with advanced educational technology

Does it sound like something you could use?

This Learning Facilitator's Manual begins with an overview of the current Alberta Education Program of Studies for Physics 20. This summary is included for inexperienced teachers or those teachers who have found themselves teaching Physics 20 when their training is in other subject areas. This brief summary is not meant to replace the Alberta Education Program of Studies, but rather to help teachers confirm the highlights of the program.

Other parts of this introduction have also been included to help teachers become familiar with this new learning package and determine how they might want to use it in their classroom.

Beyond the introduction the guide itself contains answers, models, explanations, and other tips generated by the teachers who authored this course.

The module booklets, assignment booklets, and LFMs are the products of experienced classroom teachers and distance learning specialists. It is the hope of these teachers that their experience can be shared with those who want to take advantage of it.

Overview of the Program of Studies

The *Physics 20-30 Program of Studies* will be an important document for you as a teacher of Physics 20. Once you understand the rationale behind the course and the expectations of students, you'll know how the different components work together, and you'll be able to make better decisions when planning. Starting with the program of studies is a good investment in time. So, before proceeding any further, you should get the most recent version of this document, as well as the Module 1 Student Module Booklet.

To help make the best use of your time, you'll be asked to read certain pages from the *Program of Studies* and then key ideas will be highlighted with supporting examples from the Student Module Booklet. To begin, please read Program Rationale and Philosophy on pages 1 and 2 of the *Program of Studies*.

Did you notice the emphasis on students learning the big interconnecting ideas in a relevant context? This philosophy translates into strategies such as providing an equations sheet for students during exams since the focus is not on memorizing equations, but on applying main ideas. Another example can be found on page 1 of the Module 1 Student Module Booklet. Please read this page and note the focus on main ideas being put into a relevant context.

Please read General Learner Expectations on pages 3 to 5 of the *Program of Studies*, paying particularly close attention to the section on skills. It could be argued that the skills may be of greater value to the life-long learning of the student than to the specific course content. Clearly, these skills are intended to be a central part of the course. The Student Module Booklet has attempted to make these skills explicit to the students as they progress through the course. Carefully read through pages 9 to 16 and pages 147 to 154 of the Student Module Booklet.

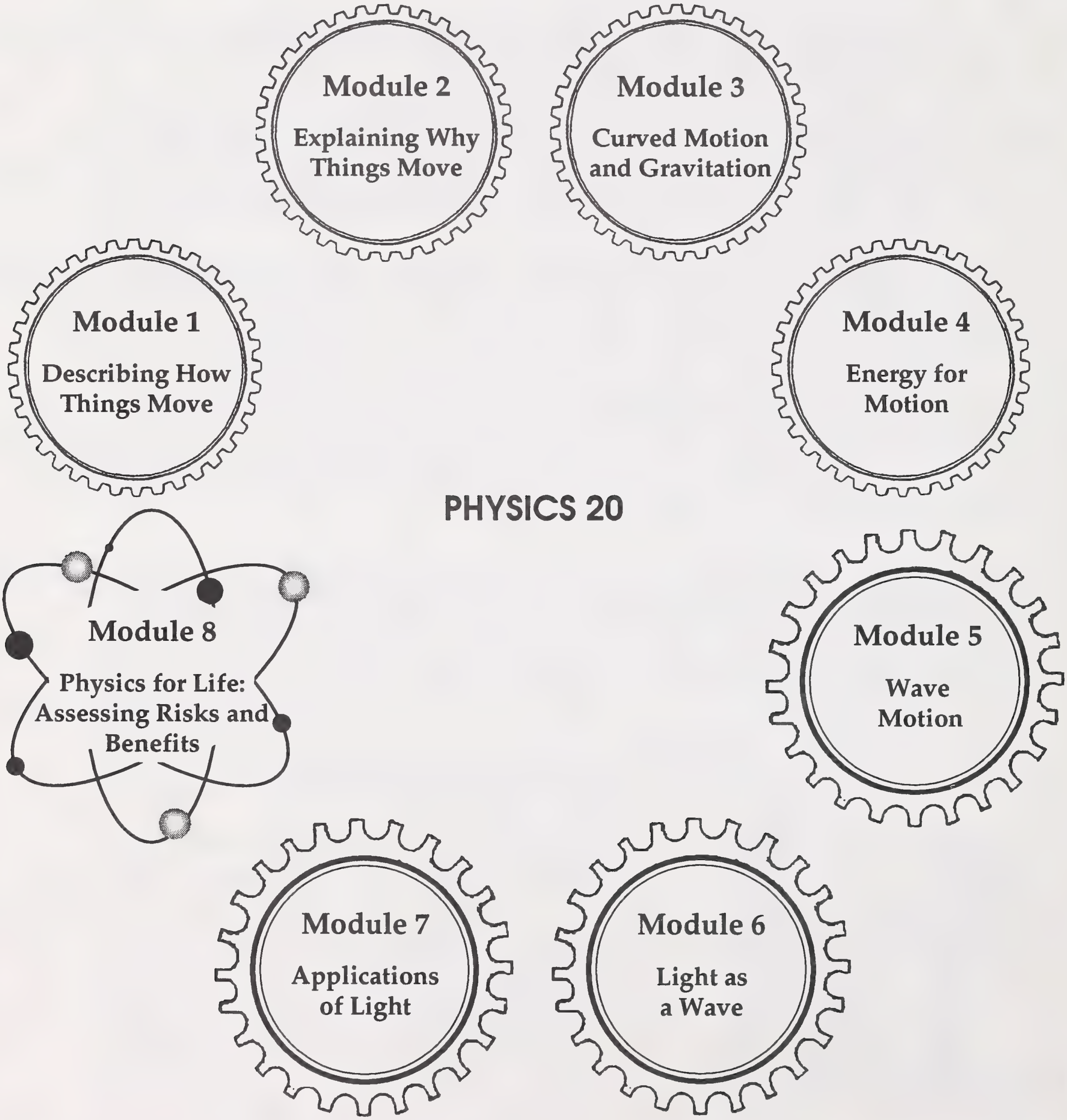
How should Physics 20 be taught? Although there are a variety of answers to this question, the learning cycle is an approach that many successful science teachers have been using for years. Please read Specific Learner Expectations on page 7 of the *Program of Studies* to learn more about the learning cycle. Examples of how the learning cycle can be applied to student learning can be found in each section of the Student Module Booklet. Please quickly survey these pages to find evidence of the learning cycle being used.

Having worked from very general statements about philosophy to the specifics of the learning cycle, it is appropriate to wonder what topics actually comprise the Physics 20 course. The following chart shows how the units outlined in the *Program of Studies* relate to the student modules produced by the Alberta Distance Learning Centre.

Physics 20 Program of Studies		**ADLC Physics 20**		**Recommended Percentage of Available Instructional Time**
Unit	**Title**	**Module**	**Title**	
1	Kinematics and Dynamics	1	Describing How Things Move	20%
		2	Explaining Why Things Move	20%
2	Circular Motion and Gravitation	3	Curved Motion and Gravitation	14%
3	Mechanical Waves	4	Energy for Motion	8%
		5	Wave Motion	10%
4	Light	6	Light as a Wave	10%
		7	Applications of Light	10%
5	Radioactivity	8	Physics for Life: Assessing Risks and Benefits	8%

Overview of Physics 20

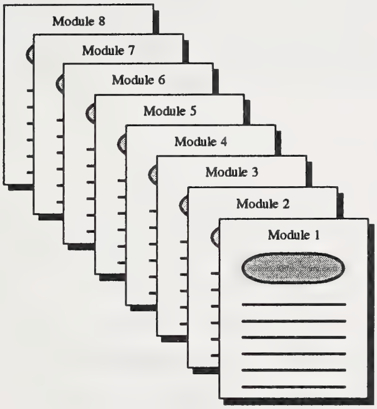
This course contains eight modules. The first four modules involve the study of motion on Earth and in the heavens. Modules 5, 6, and 7 investigate the properties and characteristics of waves in general and light waves. The last module is an introduction to nuclear physics from the point of view of risk/benefit analysis.



Structure of the Learning Package

Basic Design

This new learning package involves many other components in addition to the Learning Facilitator's Manual.



The print components involve many booklets called modules. These modules contain guided activities that instruct students in a relevant, realistic setting.

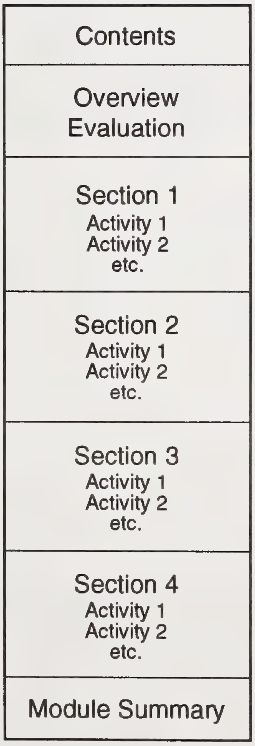
The modules have been specially designed to promote such qualities in the learner as autonomy, independence, and flexibility. Writers have incorporated such teaching strategies as working from the concrete to the abstract, linking the old to the new, getting students actively involved, and using advance, intermediate, and post organizers. Many other techniques enable learners to learn on their own for at least some of the time.

The structure of the module booklets follows a systematic design. Each module begins with a detailed table of contents which shows the students all the main steps. It acts as an organizer for students. The overview introduces the module topic or theme. A graphic representation has been included to help visual learners and poor readers. The introduction also states the weightings of each assignment.

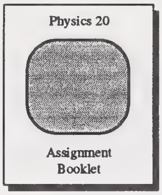
The body of the module is made up of two or more closely related sections. Each section contains student activities that develop skills and knowledge centred around a theme.

The activities may involve print, audio, video, computer, or laser videodisc formats. At times the student and the learning facilitator are allowed to choose the activity that best suits the student's needs and interests. Other activities such as the Extra Help and Enrichment are optional pathways. This flexibility caters to each student's personal situation.

The summary focuses on the skills and strategies that the student has learned.

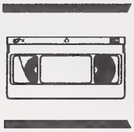


Assignment Booklet



Accompanying each module is an assignment booklet. The activities in these booklets can be used for formative and for summative assessments. The students should complete these assignment booklets when they have thoroughly reviewed the module materials. The assignment booklets have been designed for classroom use, for faxing, or for mailing. **If the booklets are not being mailed, you should remove the outside cover.**

Media



VIDEOCASSETTE

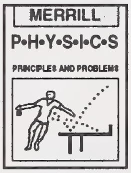
Frames 48350 - 49050

LASER
VIDEODISC

The package also includes references to media. Some types of media such as laser videodiscs are optional choices for students; however, there are activities that require students to view certain videos. These mandatory videos are listed on the following page. It is important that you acquire these videos as you are planning the course. In addition to the mandatory videos, optional videos have been mentioned at various points in the modules. A list of the optional videos is also included on the following page. More information about the videos can be found within the LFM.

Textbooks and Reference Books

The package requires students to use *Physics: Principles and Problems*, published by Maxwell Macmillan, as their textbook. Additional reference materials for teachers are indicated later in this manual.



Lab and Other Materials

The package includes references to lab materials. A list of necessary materials is included later in this manual.

Materials, Media, and Equipment

Mandatory Components

Equipment (Hardware)	Media	Materials
• VCR	• Mandatory Video List: *Vectors* (Classroom Video) *Harmonic Motion* (VEC/Criterion Video) *Properties of Waves – Non-Light* (Classroom Video) *The Physics of Music* (Classroom Video) *Wave Particle Duality: The Wave Model* (TV Ontario) *Nuclear Physics* (TV Ontario)	• LFM for Physics 20 • one complete set of module booklets (8) and assignment booklets (8) for each student • There is a final test.

Videocassettes or laser videodiscs used in the course may be available from the Learning Resources Distributing Centre or ACCESS Network. You may also wish to call your regional library service for more information.

Optional Components

Equipment (Hardware)	Media	Materials
• laser videodisc player	• videocassettes • laser videodiscs *Physics: Cinema Classics* - a set of three discs (Available from D.C. Heath Canada Ltd.) • Optional Video List: *Force and Motion: Newton's Three Laws* (VEC/Criterion Video) *Mechanical Universe: #8 The Apple and the Moon* (California Institute of Technology) *The Behaviour of Light* (VEC/Criterion Video) *Convex and Concave Lenses* (Films for the Humanities and Sciences) *Nova: Back to Chernobyl* (Vestron Video - Available from Western Cine Vision, Calgary)	

Using This Learning Package in the Classroom

Conventional Classroom

Whether your classroom has desks in rows or tables in small groups, you may be most comfortable with a learning system that you can use with all your students in a paced style. In other words, you may want a package that will suit all of your students, so they can move through the materials as one group or several small groups. Because these materials contain different routes or pathways within each module, they can address various learning styles and preferences. The materials also include many choices within the activities to cater to different thinking levels and ability levels. Because of their versatility and flexibility, these materials can easily suit a conventional classroom.

Open-Learning Classroom

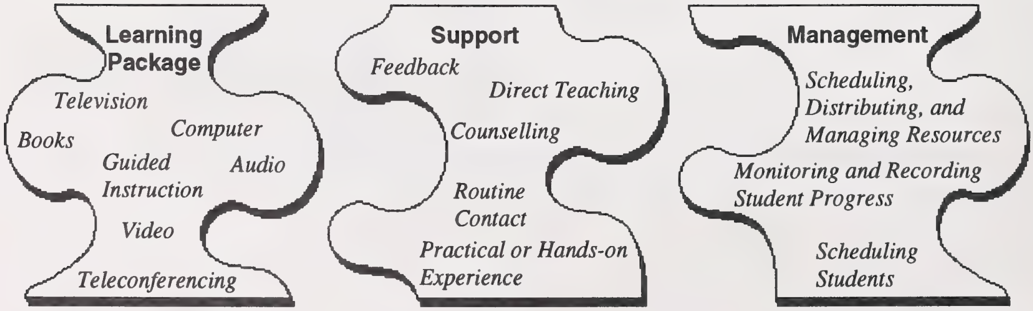
Open learning is the concept of opening up opportunities by overcoming barriers of time, pace, and place by giving the learners a package specially designed to enable them to learn on their own for at least some of the time.

Such a concept is not new. Many teachers can recite attempts to establish an individualized learning system as they recognized the importance of trying to personalize courseware to meet each individual student's needs. But these efforts often failed due to lack of time and lack of quality materials that conformed to Alberta specifications.

Due to advanced educational technology and improved Alberta-specific learning packages, a student-centred approach is now possible. Improved technology now allows us to provide support to learners individually, regardless of their pace or location. A teacher cannot be in twenty-eight places at one time offering guidance. However, media and a well-designed learning package can satisfy individual needs. Technology can also help provide an effective management system needed to track the students as they progress independently through the materials.

The key to a successful open-learning system depends on three vital elements: a learning package specially designed to enable students to learn effectively on their own for at least some of the time; various kinds of learner support; and a management system and style that ensures that the open-learning system runs smoothly.

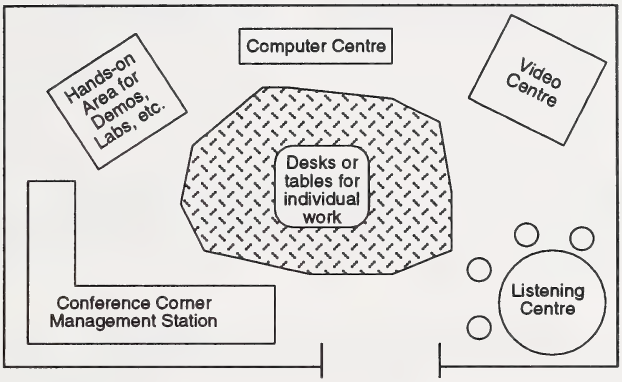
The Key to a Successful Open-Learning System



Learning Package

The specially designed learning package needed for a successful open-learning system has been developed for you. The objectives teach current Alberta specifications using strategies designed for individualized instruction. As the learning facilitator, you need to be sure to have all the components in the learning package available to students as needed.

If adequate numbers of media are available to satisfy the demand, a centre can be established for specific media.


Computer Centre
Hands-on Area for Demos, Labs, etc.
Video Centre
Desks or tables for individual work
Listening Centre
Conference Corner Management Station

You may not have the luxury to have enough hardware to set up a permanent video or computer centre in your classroom. In that case, students should be encouraged to plan ahead. Perhaps every three to five days they should preview their materials and project when they would need a certain piece of media. This would allow you to group students, if necessary, or reserve media as required.

Support

Support is definitely a key element for successful learning, and when you're planning an individualized, non-paced program, you need to carefully plan when and how support will be given.

The materials contain a form of consistent support by providing immediate feedback for activities included in the module booklet. High school students have solutions, models, explanations, and guides included in the appendix of every module booklet. These are included so students can receive immediate feedback to clarify and reinforce their basic understanding before they move on to higher levels of thinking.

As the learning facilitator, you may be needed to offer more personal guidance to those students having difficulty, or you may need to reinforce the need for students to do these activities carefully before attempting the assignments in the assignment booklet.

The activities include choices and pathways. If a student is having difficulty, you may need to encourage that student to work on all the choices rather than one. This would provide additional instruction and practice in a variety of ways.

Another form of support is routine contact with each individual. This might be achieved with a biweekly conference scheduled by you, or as students reach a certain point (e.g., after each section is completed), they may be directed to come to the conference area.

Special counselling may be needed to help students through difficult stages. Praise and encouragement are important motivators, particularly for those students who are not used to working independently.

Direct teaching may be needed and scheduled at certain points in the program. This might involve small groups or a large group. It might be used to take advantage of something timely (e.g., election, eclipse, etc.), something prescheduled like the demonstration of a process, or something involving students in a hands-on, practical experience.

Support at a distance might include tutoring by phone, teleconferencing, faxing, or planned visits. These contacts are the lifeline between learners and distance education teachers, so a warm dialogue is essential.

Management

Good management of an open-learning system is essential to the success of the program. The following areas need action to ensure that the system runs smoothly:

- Scheduling, Distributing, and Managing Resources – As discussed earlier, this may require a need for centres or a system for students to project and reserve the necessary resources.

- Scheduling Students – Students and teachers should work together to establish goals, course completion timelines, and daily timelines. Although students may push to continue for long periods of time (e.g., all morning), teachers should discourage this. Concentration, retention, and motivation are improved by taking scheduled breaks.

- Monitoring Student Progress – You will need to record when modules are completed by each student. Your data might also include the projected date of completion if you are using a student contract approach.

Sample of a Student Progress Chart

Physics 20		Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8	Final Test
Billy Adams	P									
	A									
Louise Despins	P									
	A									
Violet Klaissian	P									
	A									
P = Projected Completion Date A = Actual Completion Date										

The student could keep a personal log as well. Such tracking of data could be stored easily on a computer.

- Recording Student Assessments – You will need to record the marks awarded to each student for work completed in each module assignment booklet. The marks from these assignment booklets will contribute to a portion of the student's final mark. Other criteria may also be added (a special project, effort, attitude, etc.). Whatever the criteria, they should be made clear to all students at the beginning.

Sample of a Student Assessment Chart

Physics 20	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8	Year's Average	Final Test	Final Mark
Billy Adams	67	65	54	47	78	67			63		
Louise Despins	43	50	54	55	48	42			49		
Violet Klaissian	65	65	66	68	67	70			67		

Letter grading could easily be substituted.

- Recording Effectiveness of System – Keep ongoing records of how the system is working. This will help you in future planning.

Sample of a System Assessment Chart

Module 1			
Date	Module Booklet	Assignment Booklet	Resources/Media

The Role of the Teacher in an Open-Learning Classroom

The teachers in a conventional classroom spend a lot of time talking to large groups of learners. The situation in open learning requires a different emphasis. Teachers will probably meet learners individually or in very small groups.

With this approach it is necessary to move beyond the idea of a passive learner depending largely on a continually supportive teacher. The teacher must aim to build the student's confidence, to stimulate the learner into self-reliance, and to guide the learner to take advantage of routes that are most meaningful and applicable to the learner.

These materials are student-centred, not teacher-centred. The teacher needs to facilitate learning by providing general support to the learner.

Evaluation

Evaluation is important to the development of every learner. Data gathering and processing, and decision making, at the student and teacher level, serve as means of identifying strengths and weaknesses.

These specially designed learning packages contain many kinds of informal and formal evaluation.

Observation

In the classroom the teacher has the opportunity to see each student perform every day and to become aware of the level and nature of each student's performance.

Observations are more useful if they are recorded in an organized system. The following list of questions is a sample of types of observations and how they can be collected.

Observation Checklist

	B. Adams	L. Despins	V. Klaissian	H. Smith	K. Dalley
1. Does the student approach the work in a positive manner?					
2. Is the student struggling with the reading level?					
3. Does the student make good use of time?					
4. Does the student apply an appropriate study method?					
5. Can the student use references effectively, etc.?					

Observation may suggest a need for an individual interview with a student.

Individual Conferences

Individual conferences may be paced (scheduled) by the calendar, at certain points in the module, or they may be set up only as needed or requested.

During these conferences teachers can determine the student's progress and can assess the student's attitudes toward the subject, the program, school, and self, as well as the student's relationship with other students. With guided questions the teacher can encourage oral self-assessment; the student can discuss personal strengths or weaknesses in regard to the particular section, module, or subject area.

Self-Appraisal

Self-appraisal helps students recognize their own strengths and weaknesses. Through activities that require self-assessment, students also gain immediate feedback and clarification at early stages in the learning process. Teachers need to promote a responsible attitude toward these self-assessment activities. Becoming effective self-assessors is a crucial part of becoming autonomous learners. By instructing, motivating, providing positive reinforcement, and systematically supervising, the learning facilitator will help students develop a positive attitude toward their own progress.

For variation, students may be paired and peer-assessing may become part of the system. The teacher may decide to have the student self-assess some of the activities, have a peer assess other activities, and become directly involved in assessing the remainder of the activities.

When the activities have been assessed, the student should be directed to make corrections. This should be made clear to students right from the start. It is important to note the correct association between the question and the response to clarify understanding, aid retention, and be of use for study purposes.

Many of the activities include choices for the student. If the student is having difficulty, more practice may be warranted, and the student may need to be encouraged to do more of the choices.

Each section within a module includes additional types of activities called Extra Help and Enrichment. Students are expected to be involved in the decision as to which pathway best suits their needs. They may decide to do both.

Self-appraisal techniques can also be introduced at the individual conferences. Such questions as the following might be included:

- What steps are you taking to improve your understanding of this topic?
- What method of study do you use most?
- How do you organize your material to remember it?
- What steps do you follow when doing an assignment?
- What could you do to become an even better reader?
- Do you have trouble following directions?
- Did you enjoy this module?

A chart or checklist could be used for recording responses.

Informal Evaluation: Assignments

Informal evaluation, such as the assignments included in each module, are an invaluable aid to the teacher. They offer ongoing assessment information about the student's achievement and the behaviour and attitudes that affect that achievement.

Each module contains a separate booklet called the Assignment Booklet. This booklet assesses the knowledge or skills that the student has gained from the module. **The student's mark for the module may be based solely on the outcome of learning evident in the assignment booklet; however, you may decide to establish a value for other variables such as attitude or effort.** It is important that you establish at the beginning which outcomes will be evaluated, and that all students clearly understand what is expected.

Final Test

All LFMs include a formal final test which can be photocopied for each member of the class. The test, closely linked to the learning outcomes stated in the module booklets, gives the teacher precise information concerning what each student can or cannot do. Answers, explanations, and marking guides are also included. The value of the final test and each module is the decision of the classroom teacher. Following is a suggestion only.

Module 1 **10%**	**Module 2** **10%**	**Module 3** **7%**	**Module 4** **4%**
Module 5 **5%**	**Module 6** **5%**	**Module 7** **5%**	**Module 8** **4%**

Final Test

50%

Introducing Students to the System

Your initiation to these learning materials began with a basic survey of what was included and how the components varied. This same process should be used with the class. After the materials have been explored, a discussion might include the advantages and the disadvantages of learning independently or in small groups. The roles of the students and teacher should be analysed. The necessary progress checks and rules need to be addressed. Your introduction should motivate students and build a responsible attitude toward learning autonomously.

Skill Level

It is important for students to understand that there are certain skills that they will need in order to deal successfully with the course materials. They are listed below:

- understanding and using instructional materials (table of contents, index, list of illustrations, appendices, bibliography, and glossary)
- interpreting maps, graphs, and charts
- using reference materials
- recognizing special symbols
- using a scientific calculator

Other general skills are using reliable study methods, outlining, and learning to read at a flexible rate.

To decide the level and amount of instruction needed to accommodate the varied levels among students, you may wish to prepare and administer skill inventories or pretests. If most students need help with a particular skill, you may want to plan a total class instructional session. If only certain students lack a skill, you may want to set up a temporary skill group to help students who need it, or you may want to develop a skills file for this purpose.

Reading Level

These course materials are largely print based, but poorer readers need not be discouraged. It is important that you assure the students that these materials have been designed for easy reading. The authors have employed special strategies that lower and control the reading level. Some of them are

- the conscious selection of vocabulary and careful structuring of sentences to keep the materials at an independent reading level
- the integration of activities, examples, and illustrations to break text into appropriate-sized chunks
- the inclusion of many kinds of organizers (advance, graphic, intermediate, concept mapping, post organizers) to help give students a structure for incorporating new concepts

- the recognition that vocabulary and concepts are basic to understanding content materials and, thus, must be handled systematically (defined in context, marginal notes, footnotes, and often in a specialized glossary)

- the acknowledgement that background knowledge and experience play a vital role in comprehension

- the systematic inclusion of illustrations and videos to help poorer readers and visual learners, and audiocassettes and software as an alternative to print-based learning

- a variety of formats (paragraphs, lists, charts, etc.) to help poorer readers who do not absorb or retain main ideas easily in paragraph format

- the inclusion of media and activity choices to encourage an active rather than passive approach

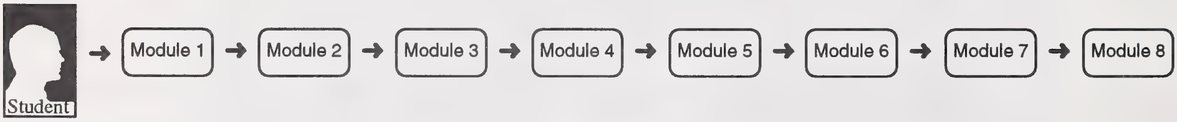
- instruction in a meaningful setting rather than in a contrived, workbook style

- using purposeful reading, viewing, and doing to produce better interpretation of the course materials

- the recognition that students need structured experiences when reading, viewing, or listening to instructional materials: developing pupil readiness, determining the purpose, providing guided instruction and feedback, rereading if necessary, and extending (This structure closely resembles the reading process.)

To help make the learning package more readable, you can begin your module preparation by reading (viewing, listening to) all the related materials that are going to be used. You need a solid background in order to assess and develop a background knowledge for students. The students' experiential bases may be assessed through brainstorming sessions concerning the topic, or by using visuals and guided questions to predict what the topic might be about.

It is important to note that Physics 20 is a course that is packed with content. Unfortunately, given the recommendations regarding skills and the learning cycle, this means that you will continually be forced to make compromises to ensure that the students finish the program. One suggestion is that the first three modules should not be rushed. These modules lay important groundwork for the whole program and can be conceptually difficult for students. The last five modules deal with topics that tend to be more descriptive and less analytical, so they offer greater opportunities for saving time. It is recommended that you do the modules in order from Module 1 to Module 8.

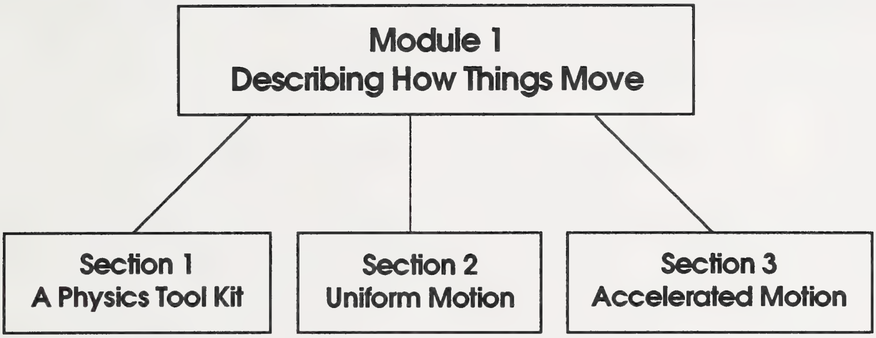


Module 1: Describing How Things Move

Overview

This module gets a physics student off to a good start by first demonstrating the kind of math skills needed to do physics. An introduction to physics and science skills precedes this math review.

Next, the concept of uniform motion is introduced both qualitatively and quantitatively. Finally, accelerated motion is done, with most of the emphasis on uniform acceleration.



It will be important for students to have a very clear understanding of the proper use of vector notation. The ADLC materials have adopted a convention that is consistent with the expectations of the Physics 30 diploma exam. Your students will appreciate it if you use the same convention in a consistent way. Unfortunately, the first edition of the textbook does not use this convention, while the second edition does. This means that your students will need to be referred to the vector notation instructions in the ADLC materials. The instructions given on page 113 of the Student Module Booklet provide a straightforward guideline to the use of vector notation in Physics 20 and 30. These guidelines can be stated as follows:

- Physics 20/30 students should be able to add and subtract vector quantities and multiply and divide vector quantities by constants or by scalar quantities.

- Physics 20/30 students should **not** be expected to multiply and divide vector quantities by other vector quantities. The only time that vectors should be multiplied or divided occurs when both vectors are colinear, in which case they can both be treated as scalars.

The distinctions made by these guidelines are not trivial. The first edition of the textbook tends to present equations with vectors multiplied and divided by other vectors. These things have been flagged and addressed in the ADLC materials. If you do not have the first edition, you should explain to your students that the errors discussed have been corrected.

Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 1. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 2

Investigation: Uniform Motion

Method A: Time to Move a Known Displacement

- measuring tape (metric) or metre stick
- heavy ball (a bowling ball, a shot, or a large steel ball bearing)

Method B: Displacement Moved in a Known Time

- interval timer
- marble
- smooth surface
- ruler or measuring tape (metric)
- butter, honey, vaseline, or oil

Section 3: Activity 3

Investigation: Measuring the Acceleration of Gravity

Method A: Time to Fall a Known Distance

- a metre stick
- a water dropper
- a cake pan
- a clock with a second hand

Method B: Using an Interval Timer

- timer
- paper tape
- weight
- ruler

Method C: Using a Pendulum

- a mass (about 200 g)
- string
- fastener
- metre stick
- clock with second hand (or stopwatch)

Method D: Using a Laser Videodisc Recording of a Falling Bowling Ball

- the laser videodisc called *Physics: Cinema Classics*
- a laser videodisc player

Additional Resources

Each of the following resources can provide additional support and information for the teacher of Physics 20.

Alberta Education. *Senior High Science Teacher Resource Manual.* Edmonton: Dept. of Education, Curriculum Branch, 1992

Giancoli, Douglas C. *Physics*. 3rd. ed. Toronto, Ontario: Prentice-Hall Canada Inc., 1991

Hewitt, Paul G. *Conceptual Physics*. Don Mills, Ontario: Addison-Wesley Publishing Company Inc., 1987

Kane, Joseph W., Sternheim, Morton M. *Physics: SI Version.* Toronto, Ontario: John Wiley & Sons Inc., 1980

Martindale, David G., et al. *Fundamentals of Physics: Combined Edition*: D.C. Heath Canada Ltd., 1992

Zitzewitz, Paul W., et al. *Physics: Principles and Problems Teacher Resource Package*. Toronto, Ontario: Maxwell Macmillan Canada Inc., 1992

The Zitzewitz textbook is the one that the ADLC materials wrap around. The teacher resource package, which includes the Teacher Wraparound Edition, are designed to help teachers make the most of the textbook. The resource package includes planning guides, strategies for teaching key concepts, answers to end of chapter problems, suggestions for enrichment and remediation, transparency masters, evaluation instruments, and supplemental lessons.

The Giancoli book is the best teacher reference for the physics concepts, providing explanations, ideas for problems, and applications at the college level. The Kane and Sterheim book is a college text that is great for the biological applications of physics. Hewitt's book takes a non-mathematical approach to physics and provides very good explanations of basic concepts at the high school level. Another high school text is the Martindale book which has a wonderful assortment of problems.

The *Senior High Science Teacher Resource Manual* includes a great variety of ideas to help teachers implement the vision of the new science curriculum.

Possible Media

Videocassettes – *Mechanical Universe: #8 The Apple and the Moon* (California Institute of Technology)

Laser Videodisc – *Physics: Cinema Classics* (1993) – Available from D.C. Heath Canada Ltd. This set of three laser videodiscs has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	25%
Section 2 Assignment	40%
Section 3 Assignment	35%
TOTAL	100%

Section 1: A Physics Tool Kit

The way physics fits into the skills of science is introduced with the continuing story of high-temperature superconductors. Then the students do two pre-tests on math and measurement skills. If they need brushing up on these, they will do the exercises there.

Students are also introduced to the use of icons to draw their attention to science skills. Students are encouraged to develop their abilities in science skills. It is a good idea to make posters of the pages explaining the science skills and the levels found in the Appendix of the Module 1 Student Module Booklet. This will be a valuable point of reference as students fine tune their skills throughout the course.

From an instructors view point, there are some important points about the model for assessing the skills of science in this program.

- For students to learn what is meant by the nature and process of science, it is essential that they spend much of their time doing science activities.

These modules have been designed to promote this kind of learning. The activities marked with the science skill icon should not be regarded as supplements — they are an integral part of the program.

- The model for assessing science skills applies to a wide variety of problem-solving activities in science. Examples would include laboratory investigations, library research projects, field surveys, interviews, and any other activity that allows students to become active problem solvers. It would be a mistake to think that the model applies only to laboratory investigations.

- The whole point of this model is to foster the **growth** of students' abilities in the area of science skills. It follows that if you were asked at the end of the course to determine the level at which a student was operating, you should determine the highest consistent level of performance. Consider the following example:

  While taking Physics 20, a student was assessed 12 times on their ability to collect and record information. The teacher kept the following records:

Date	Sept. 8	Oct. 3	Oct. 19	Nov. 2	Nov. 23	Jan. 11	Feb. 15	Mar. 6	Mar. 24	April 16	May 4	May 19
Level of Collecting & Recording	2	2	1	2	3	1	2	3	4	3	2	3

  This student seems to be performing at level 3 for the skill of collecting and recording information.

- All six skills need not be assessed at once. You will notice that throughout the Student Module Booklet that only the skills most appropriate to that activity have been identified by the icon. However, there will be some opportunities for students to demonstrate all six skills at once, particularly when they complete a major unit of study.

- It is recommended that you obtain the most recent information on the assessment model for science skills from the Student Evaluation Branch of Alberta Education.

Section 1: Assignment Answer Key (25 marks)

1. Answers will vary somewhat. Since it's so hard to make wires from the high-temperature superconductors (ceramics), scientists are using the metal alloys that work at 23 K in a liquid helium environment. These are ductile and can be worked with.

2. a. Convert to centimetres: 4.92 cm + 0.11 cm + 695 cm = 700.03 cm
   Round to the whole number = 700 cm (or equivalent)

   b. Convert to grams: $\left(1.10\times10^{-1}\text{ g}\right)-\left(4.8\times10^{-2}\text{ g}\right)=0.110\text{ g}-0.048\text{ g}$
   $=0.062\text{ g}$ (or equivalent)

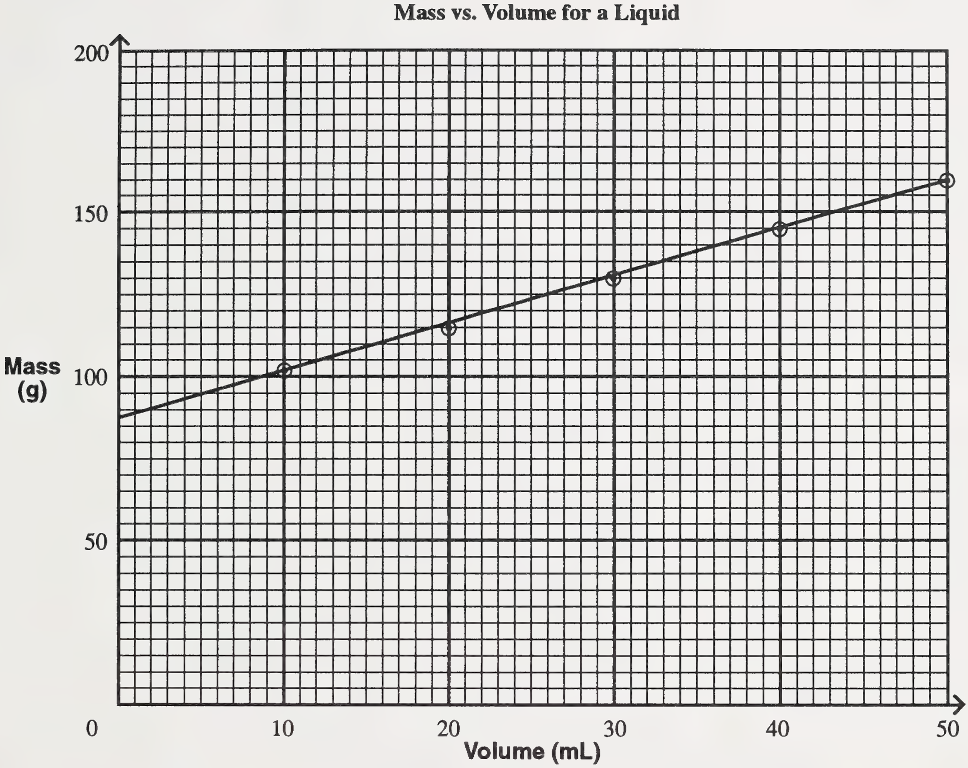
   c. Multiply and round to two significant digits:
   $18.172\ 875 = 18\text{ cm}^3$

   d. Divide and round to three significant digits:
   $0.678\ 347\ 826\ldots = 0.678\text{ m}$

   e. Multiply, divide, and round to two significant digits:
   $2.227\ 525\ 4\ldots\times10^{13} = 2.2\times10^{13}\text{ m}^2$

Award $\frac{1}{2}$ mark for the number and $\frac{1}{2}$ mark for the correct units for each part of question 2.

3. a.



Marking key for graph: 1 mark each for

- title and axis labelled
- axis scaled properly
- points correctly plotted
- best fit straight line drawn

b. $$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{(160 - 88)\text{ g}}{(50 - 0)\text{ mL}}$$
$$= 1.44\text{ g/mL}$$

c. The slope is the density of the liquid.

d. The *y*-intercept is the mass of the container.

4. a.
$$E_k = \frac{1}{2}mv^2$$
$$2E_k = mv^2$$
$$\frac{2E_k}{m} = v^2$$
$$v = \sqrt{\frac{2E_k}{m}}$$

b.
$$d = v_i t + \frac{1}{2}at^2$$
$$d - v_i t = \frac{1}{2}at^2$$
$$2(d - v_i t) = at^2$$
$$a = \frac{2(d - v_i t)}{t^2}$$

c.
$$\lambda = \frac{xd}{nl}$$
$$\lambda nl = xd$$
$$l = \frac{xd}{n\lambda}$$

d.
$$F = ma$$
$$m = \frac{F}{a}$$

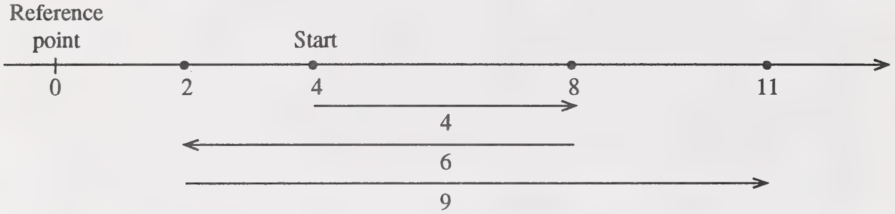
Section 2: Uniform Motion

Motion in a straight line at a constant speed is the simplest motion possible. Ways to analyse motion graphically and algebraically are presented.

Section 2: Assignment Answer Key (40 marks)

1. a. The sum of all the distances is 19 m.

b.



The final position is 11 m east.

c. The total displacement is the change in position. The total displacement is 7 m east.

d. $$v_{ave} = \frac{\text{total distance}}{\text{total time}} = \frac{19\text{ m}}{20\text{ s}} = 0.95\text{ m/s}$$

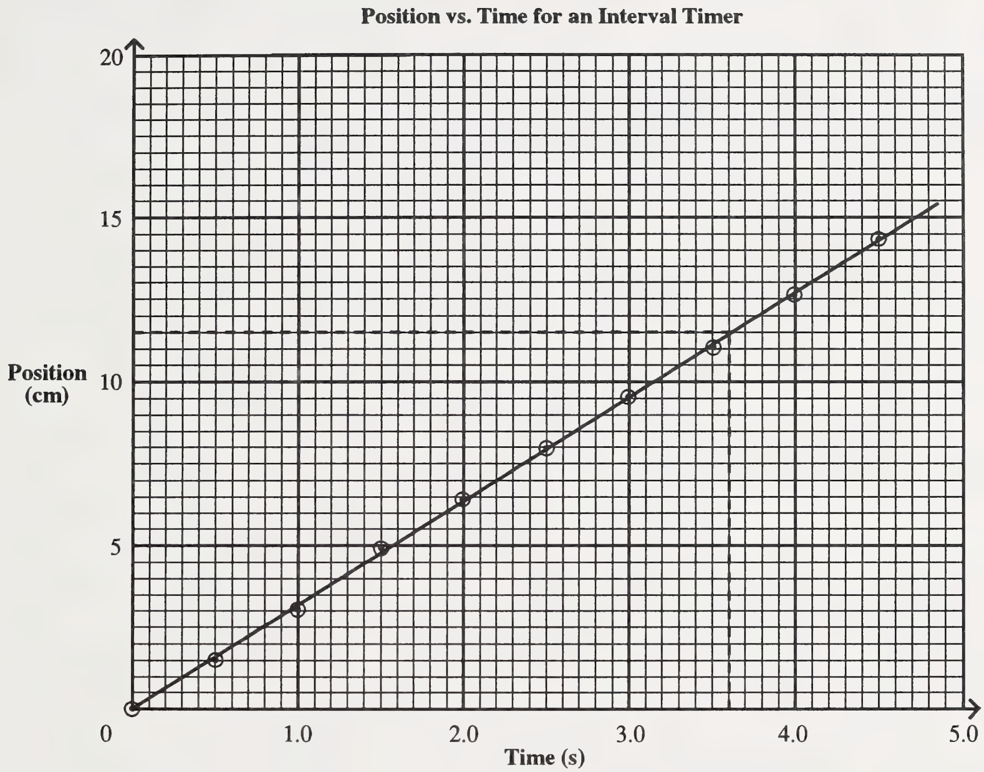
e. $$v_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{7\text{ m, east}}{20\text{ s}} = 0.35\text{ m/s, east} = 0.4\text{ m/s, east}$$

2. a.

Time (s)	Position (cm)	Displacement (cm)	Average Velocity (cm/s)
0	0		
		1.55	3.1
0.50	1.55		
		1.55	3.1
1.00	3.1		
		1.8	3.6
1.50	4.9		
		1.45	2.9
2.00	6.35		
		1.55	3.1
2.50	7.9		
		1.65	3.3
3.00	9.55		
		1.45	2.9
3.50	11.0		
		1.7	3.4
4.00	12.7		
		1.7	3.4
4.50	14.4		

Allow for some latitude in these answers. The dots are purposely large to encourage students to estimate and make good decisions.

b.



Suggested marking key items:

- title
- axis labelled with units
- proper scaling of axis
- plotting of points
- best fit straight line (drawn with a ruler)

c. $\text{slope} = \dfrac{\text{rise}}{\text{run}}$

$= \dfrac{11.5\ \text{cm} - 0\ \text{cm}}{3.6\ \text{s} - 0\ \text{s}}$

$= 3.2\ \text{cm/s}$

When marking, make sure that the two points are on the student's line and that the slope is within the range of 3.1 cm/s to 3.3 cm/s.

d. Yes, the slope is a reasonable value since it agrees with the average velocity values calculated in 2. a.

3. a. Using the graph, $\vec{d} = 56\ \text{m}$.

b. The maximum displacement from the start is 56 m.

c. $\bar{v} = \dfrac{\vec{d}}{t} = \dfrac{+28\ \text{m}}{8\ \text{s}} = 3.5\ \text{m/s}$

d. $\vec{v} = \frac{\vec{d}}{t} = \frac{-56\ \text{m}}{20\ \text{s}} = -2.8\ \text{m/s}$

e. Since the position is not changing, the bicycle is stopped.

f. The total displacement is zero. Therefore, the average velocity is zero.

$$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{0}{40\ \text{s}} = 0$$

4. a. The maximum velocity is 16 m/s. This velocity occurs in the time interval from 35 s to 50 s.

b. It means the car is moving in the direction opposite to its original direction.

c. The displacements can all be determined by finding the area under the curve for each time interval.

Time Interval	Area Under the Curve
0 s to 14 s	$A = lw = (9\ \text{m/s})(14\ \text{s}) = 126\ \text{m}$
14 s to 30 s	$A = lw = (0)(16) = 0$
30 s to 35 s	$A = lw = (-4\ \text{m/s})(5\ \text{s}) = -20\ \text{m}$
35 s to 50 s	$A = lw = (16\ \text{m/s})(15\ \text{s}) = 240\ \text{m}$

d. The total displacement is the sum of the individual displacements.

$$\Delta \vec{d} = (126\ \text{m}) + (0\ \text{m}) + (-20\ \text{m}) + (240\ \text{m}) = 346\ \text{m}$$

e. $\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{346\ \text{m}}{50\ \text{s}} = 6.92\ \text{m/s}$

The answer should not have more than three significant digits.

5. $\vec{d} = 2.85\ \text{km}$

$t = 28\ \text{min} = 0.467\ \text{h}$

$\vec{v} = ?$

$$\vec{v} = \frac{\vec{d}}{t} = \frac{2.85\ \text{km}}{0.467\ \text{h}} = 6.1\ \text{km/h}$$

It would also be correct to express this answer as 1.7 m/s.

6. a. The displacement for walking north is calculated as follows:

$\vec{d} = ?$

$\vec{v} = +6.5\ \text{km/h}$

$t = 32\ \text{min} = 0.533\ \text{h}$

$$\vec{v} = \frac{\vec{d}}{t}$$

$$\begin{aligned}\vec{d} &= \vec{v}t \\ &= (6.5\ \text{km/h})(0.533\ \text{h}) \\ &= 3.467\ \text{km}\end{aligned}$$

The displacement for running south is calculated as follows:

$\vec{d} = ?$

$\vec{v} = -18.5\ \text{km/h}$

$t = 3.0\ \text{min} = 0.050\ \text{h}$

$$\begin{aligned}\vec{v} &= \frac{\vec{d}}{t}\\ \vec{d} &= \vec{v}t\\ &= (-18.5\ \text{km/h})(0.050\ \text{h})\\ &= -0.925\ \text{km}\end{aligned}$$

$$\begin{aligned}v_{ave} &= \frac{\Delta d}{\Delta t}\\ &= \frac{(3.467\ \text{km}) + (0.925\ \text{km})}{(0.533\ \text{h}) + (0.050\ \text{h})}\\ &= 7.5\ \text{km/h}\end{aligned}$$

Note that direction is not considered for average speed.

b. $$\begin{aligned}\vec{v}_{ave} &= \frac{\Delta \vec{d}}{\Delta t}\\ &= \frac{(+3.467\ \text{km}) + (-0.925\ \text{km})}{(0.533\ \text{h}) + (0.050\ \text{h})}\\ &= +4.4\ \text{km/h}\\ &= 4.4\ \text{km/h, north}\end{aligned}$$

Note that direction is considered here.

7.
- If you averaged 40 km/h for 40 km, this would take 1.00 h.
- To complete the 90-km trip at 60 km/h, it would take 1.50 h. Therefore, there is only 0.50 h left to complete the remaining 50 km.
- $\vec{d} = +50\ \text{km}$
  $t = 0.50\ \text{h}$
  $\vec{v} = ?$

$$\begin{aligned}\vec{v} &= \frac{\vec{d}}{t}\\ &= \frac{+50\ \text{km}}{0.50\ \text{h}}\\ &= 100\ \text{km/h}\end{aligned}$$

8.
- Determine how far ahead Juanita has travelled.

$\vec{d} = ?$

$\vec{v} = 4.5\ \text{km/h}$

$t = 45\ \text{min} = 0.75\ \text{h}$

$$\begin{aligned}\vec{v} &= \frac{\vec{d}}{t}\\ \vec{d} &= \vec{v}t\\ &= (4.5\ \text{km/h})(0.75\ \text{h})\\ &= 3.375\ \text{km}\end{aligned}$$

- In order to catch up, you must travel 3.375 km in 1 h while travelling the same distance that Juanita did in 1 h.

$\vec{d} = 4.5\ \text{km} + 3.375\ \text{km}$

$\quad = 7.875\ \text{km}$

$t = 1\ \text{h}$

$\vec{v} = ?$

$$\begin{aligned}\vec{v} &= \frac{\vec{d}}{t}\\ &= \frac{7.875\ \text{km}}{1\ \text{h}}\\ &= 7.9\ \text{km/h}\end{aligned}$$

Section 3: Accelerated Motion

In this section the ideas of velocity changes and acceleration are introduced. The graphing ideas from Section 2 are extended to include acceleration. A lab is done to show students how to get an acceleration value from a set of dots made with an interval timer. Finally, the full algebraic treatment of acceleration is presented and the students have the opportunity to measure g, the acceleration due to gravity.

Section 3: Assignment Answer Key (35 marks)

1. $\vec{v}_f = 18.0\ \text{km/h} = 5.00\ \text{m/s}$

$\vec{v}_i = 0\ \text{m/s}$

$t = 8.0\ \text{s}$

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_f - \vec{v}_i}{t}\\ &= \frac{5.00\ \text{m/s} - 0\ \text{m/s}}{8.0\ \text{s}}\\ &= 0.63\ \text{m/s}^2\end{aligned}$$

2. Acceleration is a change in velocity. Slowing down is also a velocity change. A change of direction with or without a change in speed is also an acceleration.

3. $\vec{v}_i = 0\ \text{m/s}$

$\vec{d} = ?$

$\vec{a} = \vec{g} = -9.80\ \text{m/s}^2$

$t = 3.85\ \text{s}$

$(v_f\ \text{missing})$

$$\begin{aligned}\vec{d} &= \vec{v}_i t + \frac{1}{2}\vec{a}t^2\\ &= 0\ \text{m/s} + \frac{1}{2}(-9.80\ \text{m/s}^2)(3.85\ \text{s})^2\\ &= -72.630\,25\ \text{m}\\ &= -72.6\ \text{m}\end{aligned}$$

Since the displacement of the landing position is 72.6 m below the cliff, the cliff is 72.6 m high.

4. $v_i = 0\ \text{m/s}$

$v_f = 12.3\ \text{m/s}$

$d = 2.80\ \text{m}$

$a = ?$

$(t\ \text{missing})$

$$\begin{aligned}v_f^2 &= v_i^2 + 2ad\\ a &= \frac{v_f^2 - v_i^2}{2d}\\ &= \frac{(12.3\ \text{m/s})^2 - (0\ \text{m/s})^2}{2(2.80\ \text{m})}\\ &= 27.0\ \text{m/s}^2\end{aligned}$$

5. a. $$\begin{aligned}\bar{a} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{10\ \text{m/s}}{4.0\ \text{s}}\\ &= 2.5\ \text{m/s}^2\end{aligned}$$

b. $$\begin{aligned}\bar{a} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{-10\ \text{m/s}}{3.0\ \text{s}}\\ &= -3.3\ \text{m/s}^2\end{aligned}$$

c. $$\bar{a} = \frac{\Delta\vec{v}}{\Delta t}$$

Since there is no change in the velocity, the acceleration is also zero.

d. The displacements can be found by finding the area under the graph for each time interval.

Time Interval	Shape of Area	Calculation of Area
0 s to 4 s	triangle	$A = \frac{1}{2}ab = \frac{1}{2}(+10\ \text{m/s})(4\ \text{s}) = +20\ \text{m}$
4 s to 7 s	rectangle	$A = lw = (+10\ \text{m/s})(3\ \text{s}) = +30\ \text{m}$
7 s to 10 s	triangle	$A = \frac{1}{2}ab = \frac{1}{2}(+10\ \text{m/s})(3\ \text{s}) = +15\ \text{m}$
10 s to 13 s	line	$A = 0$
13 s to 15 s	triangle	$A = \frac{1}{2}ab = \frac{1}{2}(-8\ \text{m/s})(2\ \text{s}) = -8\ \text{m}$
15 s to 20 s	rectangle	$A = lw = (-8\ \text{m/s})(5\ \text{s}) = -40\ \text{m}$

The total displacement is the sum of the individual displacements.

$$\Delta \vec{d} = (20\text{ m}) + (30\text{ m}) + (15\text{ m}) + (-8\text{ m}) + (-40\text{ m}) = 17\text{ m}$$

$$\vec{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+17\text{ m}}{20\text{ s}} = 0.85\text{ m/s}$$

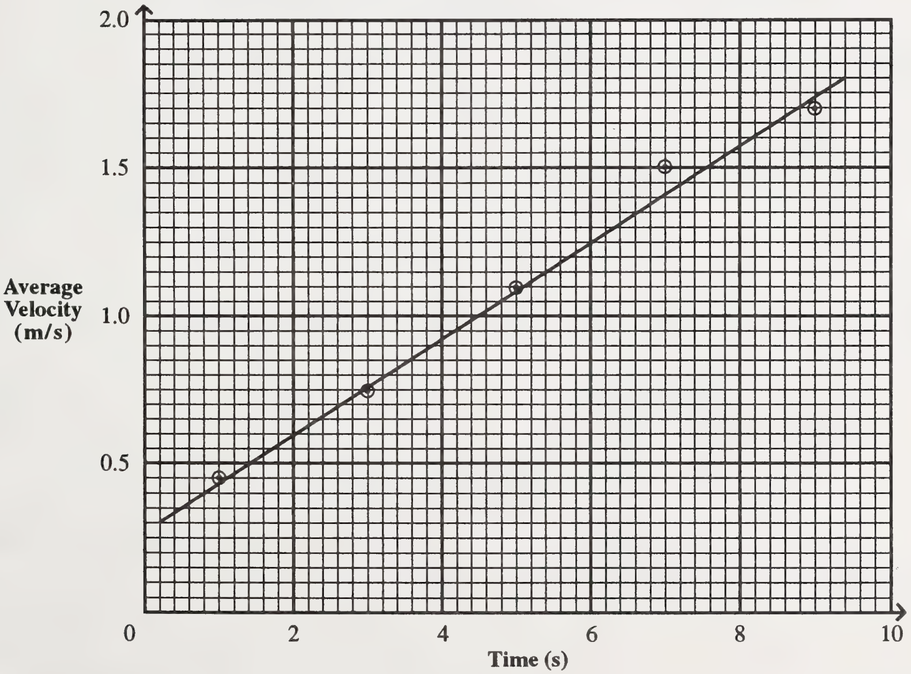
6. a. Note that this question should have read “on a moon” and not “on the moon”. The data presented does not match Earth's moon, but instead is for some other smaller moon.

Time (s)	Position (m)	Displacement (m)	Average Velocity (m/s)
0	0		
		0.9	0.45
2.0	0.9		
		1.5	0.75
4.0	2.4		
		2.2	1.1
6.0	4.6		
		3.0	1.5
8.0	7.6		
		3.35	1.675
10.0	10.95		

Only the first two columns are essential for the answer to this question. The other two columns will help with the other parts of the question.

b.

Average Velocity vs. Time for a Falling Moon Rock



c. $$a = \text{slope} = \frac{\text{rise}}{\text{run}}$$

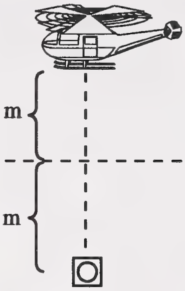
$$= \frac{(1.75\ \text{m/s}) - (0.5\ \text{m/s})}{(9.0\ \text{s}) - (1.4\ \text{s})}$$

$$= 0.16\ \text{m/s}^2$$

Note that the acceleration on the surface of the Earth's moon is actually $1.6\ \text{m/s}^2$.

7. - The helicopter is rising with uniform motion. Let up be positive.

$$\vec{d} = \vec{v}t$$
$$= (+4.0\ \text{m/s})(2.0\ \text{s})$$
$$= +8.0\ \text{m (upwards)}$$



- The camera is accelerating.

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{g}t^2$$
$$= (+4.0\ \text{m/s})(2.0\ \text{s}) + \frac{1}{2}(-9.80\ \text{m/s}^2)(2.0\ \text{s})^2$$
$$= +8.0\ \text{m} - 19.6\ \text{m} = -11.6\ \text{m (downwards)}$$

- As shown in the sketch, the distance of separation is 19.6 m or 20 m to two significant digits.

Helicopter: $\vec{d} = \vec{v}t$ Camera: $\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{g}t^2$

equal

Therefore $$\vec{d} = \vec{v}t - \left(\vec{v}_i t + \frac{1}{2}\vec{g}t^2\right)$$
$$= -\frac{1}{2}at^2$$
$$= -\frac{1}{2}(-9.80\ \text{m/s}^2)(2.0\ \text{s})^2$$
$$= 19.6\ \text{m}$$
$$= 20\ \text{m}$$

8. $a = -11.2\ \text{m/s}^2$

$v_i = 90.0\ \text{km/h} = 25.0\ \text{m/s}$

$v_f = 0\ \text{m/s}$

$d = ?$

$$v_f^2 = v_i^2 + 2ad$$
$$2ad = v_f^2 - v_i^2$$
$$d = \frac{v_f^2 - v_i^2}{2a}$$
$$= \frac{(0\ \text{m/s})^2 - (25.0\ \text{m/s})^2}{2(-11.2\ \text{m/s}^2)}$$
$$= 27.9\ \text{m}$$

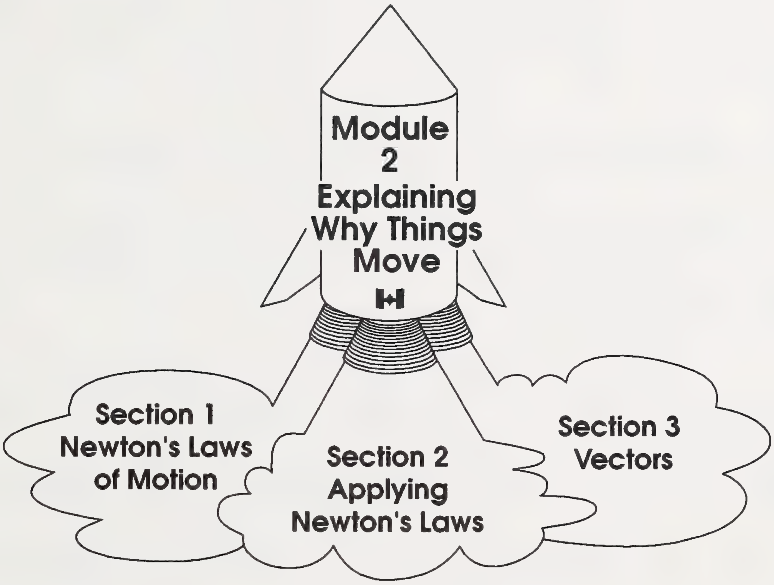
The car takes 27.9 m to stop. Since the hole is 30.0 m away, it does not hit the hole.

Module 2: Explaining How Things Move

Overview

This module examines the relationships between forces and motion by introducing Newton's three laws of motion. A ticker tape lab helps derive Newton's second law and all three laws are looked at in terms of momentum. The concept of impulse is introduced.

The force of friction is examined and the coefficients of static and sliding friction are defined. In the third section vectors are introduced. Students will add vectors graphically and algebraically in one and two dimensions. Vector addition by resolving into horizontal and vertical components is emphasized. Forces in equilibrium are studied and the equilibrant is defined.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 2. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 1

Investigation: Demonstrating Newton's First Law of Motion

- a smooth piece of cardboard (an index card or a playing card)
- a penny
- a glass

Section 1: Activity 2

Investigation: Mass and Acceleration

Part A

- spark timer
- ticker tape

- a long table that is about 1 m tall
- rolling cart
- scale
- various masses
- tape
- string
- pulley
- a metre stick or clear plastic ruler

Part B

- scissors
- transparent tape

Section 2: Activity 2

Students will do **one** of the following investigations.

Part A

Investigation: An Actual Elevator Ride

- the laser videodisc called *Physics: Cinema Classics*
- a laser videodisc player

Part B

Investigation: A Simulated Elevator Ride

- a 10-N spring scale
- an empty pop can
- water
- 10 cm of masking tape

Section 3: Activity 2

Students will do **one** of the following investigations.

Part A

Investigation: River Crossing

- the laser videodisc called *Physics: Cinema Classics*
- a laser videodisc player
- a sheet of clear thick (at least 1 mil) plastic large enough to cover the screen of the television
- at least two different coloured permanent markers

Part B

Investigation: Crossing a Paper River

- small battery-powered car
- metre stick
- protractor
- stopwatch
- single sheet of paper about 1 m × 10 m

If you don't have a little car which moves at uniform speed, you could substitute a marble for the car. Use a large marble because it will have more inertia than a small marble. You will need a marble launcher. A marble launcher is provided at the end of the Appendix of the Student Module Booklet.

Section 3: Activity 3

Investigation: Forces in Equilibrium

- long stick (a broom handle would work fine)
- 355-mL empty pop can
- two 10-N spring scales
- masking tape
- protractor

Additional Resources

- The same resources listed for Module 1 can provide additional support and information for teaching Module 2. Please refer to the list presented for Module 1.

- Students may find the video series called *Vectors* (TV Ontario) to be very helpful. This series contains six ten-minute programs which help to reinforce the main ideas. This video is available from ACCESS Network.

Possible Media

Videocassettes – *Vectors* (1987) Classroom Video (Available from ACCESS Network)
– *Force and Motion: Newton's Three Laws* (VEC/Criterion Video)

Laser Videodisc – *Physics: Cinema Classics* (1993) – Available from D.C. Heath Canada Ltd. This set of three laser videodiscs has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	36%
Section 2 Assignment	27%
Section 3 Assignment	37%
TOTAL	100%

Section 1: Newton's Laws of Motion

This section emphasizes dynamics. Newton's three laws are introduced to explain why objects move the way they do. Forces are studied by comparing the four fundamental forces and the differences between weight and mass. Newton's second law is derived by studying ticker tape data which allows graphing techniques initiated in Module 1 to be reviewed and applied.

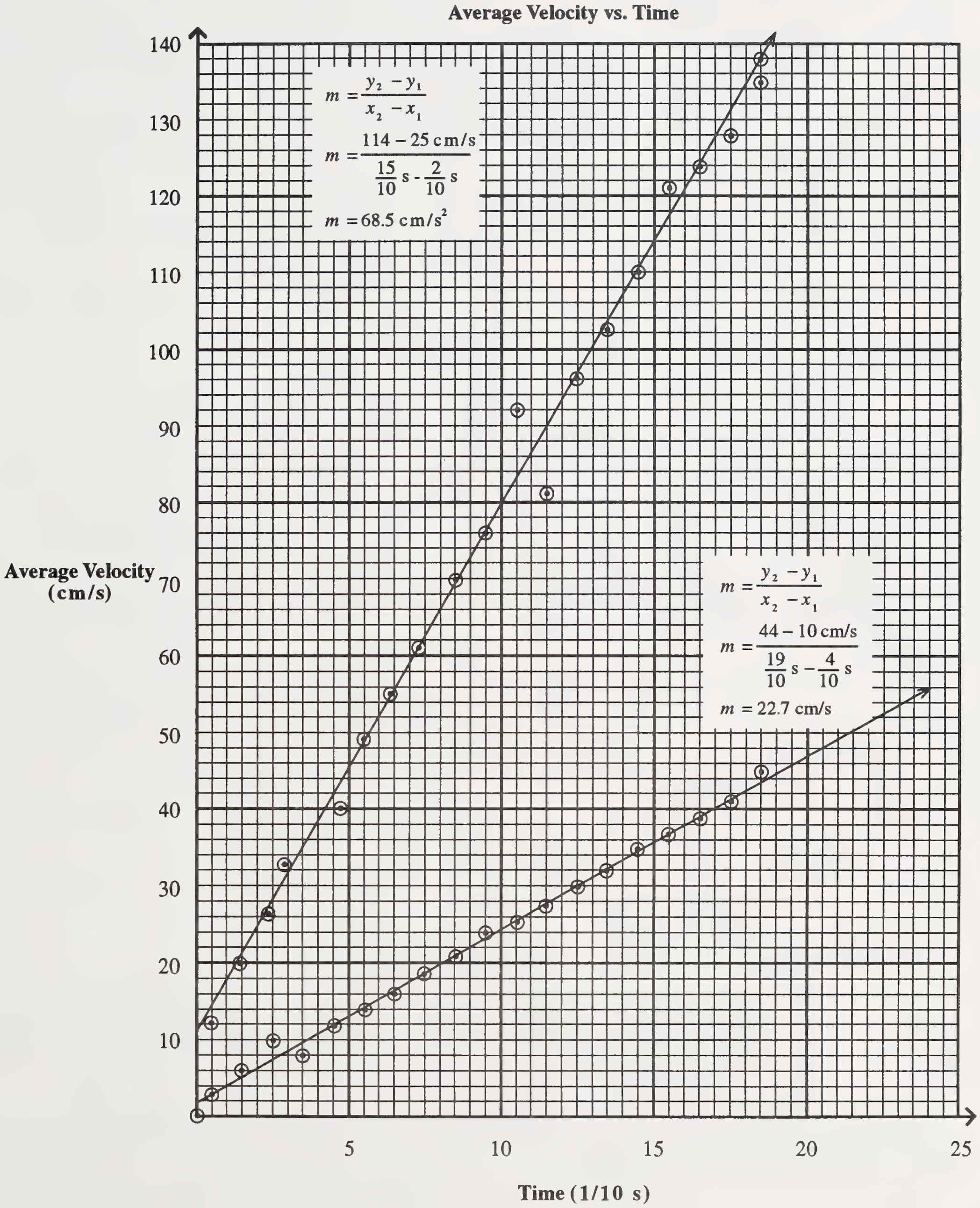
Obviously, doing the ticker tape lab is far superior to using the supplied tapes. If you don't have access to a spark timer, the supplied tape is your next best alternative and you can compare your results with those given.

Section 1: Assignment Answer Key (36 marks)

1. a. See Tables 1 and 2 (3 marks for the first column of each table, 2 marks for the second column, 1 mark for last column)

TABLE 1				TABLE 2			
Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)	Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)
0	0	–	–	0	0	–	–
1	0.3	0.3	3.0	1	1.2	1.2	12
2	0.9	0.6	6.0	2	3.2	2.0	20
3	1.9	1.0	10	3	5.8	2.6	26
4	2.7	0.8	8.0	4	9.0	3.2	32
5	3.9	1.2	12	5	13.0	4.0	40
6	5.3	1.4	14	6	17.9	4.9	49
7	6.9	1.6	16	7	23.4	5.5	55
8	8.8	1.9	19	8	29.5	6.1	61
9	10.9	2.1	21	9	36.5	7.0	70
10	13.3	2.4	24	10	44.1	7.6	76
11	15.8	2.5	25	11	53.3	9.2	92
12	18.6	2.8	28	12	61.4	8.1	81
13	21.6	3.0	30	13	71.0	9.6	96
14	24.8	3.2	32	14	81.3	10.3	103
15	28.3	3.5	35	15	92.3	11	110
16	32.0	3.7	37	16	104.4	12.1	121
17	35.9	3.9	39	17	116.8	12.4	124
18	40.0	4.1	41	18	129.6	12.8	128
19	44.5	4.5	45	19	143.1	13.5	135

b. See the graph (3 marks for each best fit line and 3 marks for each slope calculation)



$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$m = \frac{114 - 25\ \text{cm/s}}{\frac{15}{10}\ \text{s} - \frac{2}{10}\ \text{s}}$$

$$m = 68.5\ \text{cm/s}^2$$

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$m = \frac{44 - 10\ \text{cm/s}}{\frac{19}{10}\ \text{s} - \frac{4}{10}\ \text{s}}$$

$$m = 22.7\ \text{cm/s}$$

c. Force is the manipulated variable in the experiment. Time is the manipulated variable on the graph.

d. Acceleration is the responding variable in the experiment. Velocity is the responding variable on the graph.

e. It can be inferred that the force was about three times greater in the second case since the acceleration was about three times larger.

f. The time between sparks would be $\frac{1}{50}$ of a second or 0.020 s.

2. The net force would be 4.8×10^3 N.

$m = 1200$ kg
$\vec{a} = 4.0\ \text{m/s}^2$
$\vec{F}_{net} = ?$

$$\begin{aligned}\vec{F}_{net} &= m\vec{a}\\ &= (1200\ \text{kg})(4.0\ \text{m/s}^2)\\ &= 4800\ \text{N}\\ &= 4.8 \times 10^3\ \text{N}\end{aligned}$$

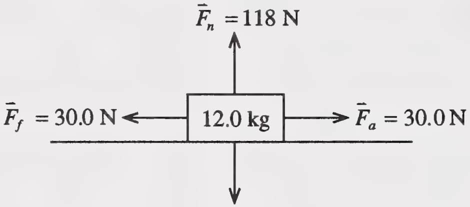
3. The net force would be -5.7×10^2 N.

$m = 245$ kg
$\vec{v}_i = 12$ m/s
$\vec{v}_f = 0$ m/s
$\Delta t = 5.2$ s
$\vec{F}_{net} = ?$

$$\begin{aligned}\vec{F}_{net} &= m\left(\frac{\vec{v}_f - \vec{v}_i}{\Delta t}\right)\\ &= (245\ \text{kg})\left(\frac{0\ \text{m/s} - 12\ \text{m/s}}{5.2\ \text{s}}\right)\\ &= -5.7 \times 10^2\ \text{N}\end{aligned}$$

4. Your mass would be the same, but your weight would be less because the moon's acceleration due to gravity is less.

5. If the car comes to a sudden stop while driving, your body will have a tendency to remain in motion unless acted on by an unbalanced force, like the seatbelt. The second collision occurs when you fly forwards and hit the windshield. A seatbelt prevents your inertia from carrying you forwards.

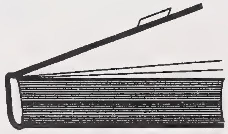


$$\begin{aligned}\vec{W} &= m\vec{g}\\ &= (12.0\ \text{kg})(-9.8\ \text{m/s}^2)\\ &= -117.6\ \text{N}\end{aligned}$$

Section 2: Applying Newton's Laws

In this section Newton's three laws are applied to problem solving. The force of friction is introduced and the coefficients of static and sliding friction are defined. The concept of net force is derived by examining the various forces that can simultaneously act on a body. Net forces are used to calculate accelerations of bodies and to relate to the sensations of an elevator ride. All three laws are looked at in terms of momentum and the concept of impulse is introduced.

One possible way to introduce the topic of static and sliding friction is to have the students lay their calculators or erasers on top of the textbook and slowly open the cover of the textbook. Ask the students why the objects don't move until a certain angle is reached. As a conclusion, you can discuss how lubricants work.



Section 2: Assignment Answer Key (27 Marks)

1. a. Textbook question 15:

- The normal force is equal and opposite to the weight because the surface is horizontal
- The accelerating force is equal and opposite to the frictional force because the acceleration of the block is zero.

$$F_f = \mu F_N$$

$$\mu = \frac{F_f}{F_N} = \frac{30.0\ \text{N}}{117.6\ \text{N}} = 0.255$$

b. Textbook question 24:

$$\begin{aligned} F_f &= \mu F_N \\ &= (0.20)(1960\ \text{N}) \\ &= 392\ \text{N} \end{aligned}$$

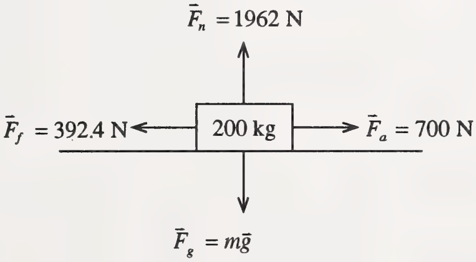
$$\begin{aligned} \vec{F}_{net} &= \vec{F}_{applied} + \vec{F}_f \\ &= +700\ \text{N} - 392\ \text{N} \\ &= +308\ \text{N} \end{aligned}$$

$$\vec{F}_{net} = m\vec{a}$$

$$\frac{\vec{F}_{net}}{m} = \vec{a}$$

$$\vec{a} = \frac{308\ \text{N}}{200\ \text{kg}}$$

$$\vec{a} = 1.5\ \text{m/s}^2$$



$$\begin{aligned} &= 200\ \text{kg}\,(-9.80\ \text{m/s}^2) \\ &= -1960\ \text{N} \end{aligned}$$

c. Textbook question 25:

$$\vec{F}_{net} = \vec{F}_{down} + \vec{F}_{up}$$

$$\vec{F}_{net} = -19\,600\ \text{N} + (2.96 \times 10^4\ \text{N})$$

$$\vec{F}_{net} = +10\,000\ \text{N}$$

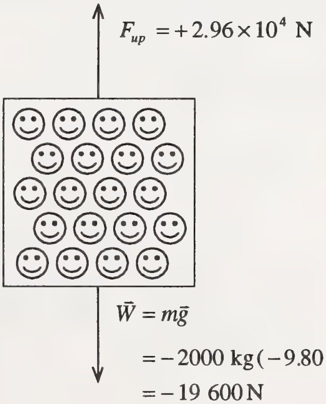
$$m\vec{a} = +10\,000\ \text{N}$$

$$m\vec{a} = +10\,000\ \text{N}$$

$$\vec{a} = \frac{+10\,000\ \text{N}}{2000\ \text{kg}}$$

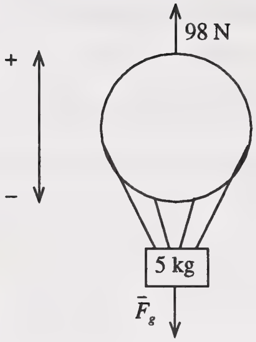
$$= +5.0\ \text{m/s}^2$$

$$\begin{aligned} 20 \times 75\ \text{kg} &= 1500\ \text{kg} \\ &+ 500\ \text{kg} \\ \hline \text{Total mass} &= 2000\ \text{kg} \end{aligned}$$



$$\begin{aligned} &= -2000\ \text{kg}(-9.80\ \text{m/s}^2) \\ &= -19\,600\,\text{N} \end{aligned}$$

d. Textbook question 26. a.:



$$\vec{F}_g = m\vec{g}$$

$$\vec{F}_g = (5\ \text{kg})(-9.80\ \text{m/s}^2)$$

$$= -49\ \text{N}$$

$$\vec{F}_{net} = \vec{F}_g + \vec{F}_a$$

$$\vec{F}_{net} = -49\ \text{N} + 98\ \text{N}$$

$$\vec{F}_{net} = +49\ \text{N}$$

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{+49\ \text{N}}{5.0\ \text{kg}} = +9.8\ \text{m/s}^2$$

Textbook question 26. b.:

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$= 0\ \text{m/s} + \left(+9.8\ \text{m/s}^2\right)(10\ \text{s})$$

$$= +98\ \text{m/s}$$

Textbook question 26. c.:

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{F}_{net} = (5.0\ \text{kg})\left(-9.80\ \text{m/s}^2\right)$$ (Only the force of gravity acts.)

$$= -49\ \text{N}$$

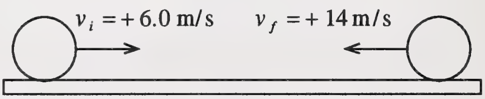
Textbook question 26. d.:

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$0\ \text{m/s} = (+98\ \text{m/s}) + \left(-9.80\ \text{m/s}^2\right)t$ (When $v_f = 0\ \text{m/s}$, the instruments have reached their highest point.)

$$t = 10\ \text{s}$$

2. a. Textbook question 8:



$$\vec{F}_{net} = m\vec{a}$$

$$\vec{F} = m\left(\frac{\vec{v}_f - \vec{v}_i}{t}\right)$$

$$\vec{F} = 0.25\ \text{kg}\left(\frac{(-14\ \text{m/s}) - (6\ \text{m/s})}{2.0 \times 10^{-2}\ \text{s}}\right)$$

$$\vec{F} = -2.5 \times 10^2\ \text{N}$$

b. Textbook question 15. a.:

Find the final speed when falling from 0.32 m.

$$\begin{aligned} v_f^{\,2} &= v_i^{\,2} + 2ad \\ v_i &= 0 \text{ m/s} \\ \therefore\; v_f &= \sqrt{2ad} \\ &= \sqrt{2\left(9.80 \text{ m/s}^2\right)\left(0.32 \text{ m}\right)} \\ &= 2.50 \text{ m/s} \end{aligned}$$

The velocity is -2.50 m/s.

$$\begin{aligned} \vec{p} &= m\vec{v} \\ &= \left(60 \text{ kg}\right)\left(-2.50 \text{ m/s}\right) \\ &= -1.5 \times 10^2 \text{ kg} \bullet \text{m/s} \end{aligned}$$

Textbook question 15. b.:

$$\begin{aligned} \text{Impulse} = \vec{F}\Delta t &= \Delta\vec{p} \\ &= \vec{p}\,' - \vec{p} \\ &= 0 - \left(-1.5 \times 10^2 \text{ kg} \bullet \text{m/s}\right) \\ &= +1.5 \times 10^2 \text{ kg} \bullet \text{m/s} \end{aligned}$$

Textbook question 15. c.:

$$\begin{aligned} \text{Impulse} = \vec{F}\Delta t &= +1.5 \times 10^2 \text{ kg} \bullet \text{m/s} \\ \vec{F} &= \frac{+1.5 \times 10^2 \text{ kg} \bullet \text{m/s}}{\Delta t} \\ &= \frac{+1.5 \times 10^2 \text{ kg} \bullet \text{m/s}}{0.050 \text{ s}} \\ &= +3.0 \times 10^3 \text{ N} \end{aligned}$$

Textbook question 15. d.:

$$\frac{F_{stop}}{F_g} = \frac{3.0 \times 10^3 \text{ N}}{\left(60 \text{ kg}\right)\left(9.80 \text{ m/s}^2\right)} = 5.1$$

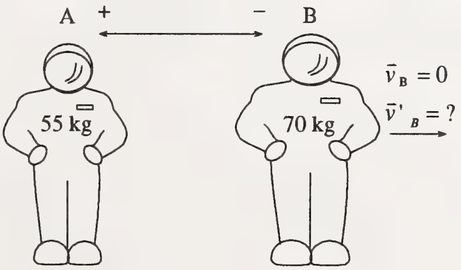
The stopping force is 5.1 times bigger than the dancer's weight.

3.

$$\begin{aligned} \Delta\vec{p}_A &= -\Delta\vec{p}_B \\ m_A\Delta\vec{v}_A &= -m_B\Delta\vec{v}_B \\ m_A\left(\vec{v}_A{}' - \vec{v}_A\right) &= -m_B\left(\vec{v}_B{}' - \vec{v}_B\right) \\ m_A\vec{v}_A{}' &= -m_B\vec{v}_B{}' \\ \vec{v}_B{}' &= \frac{-m_A\vec{v}_A{}'}{m_B} \\ &= \frac{-\left(55 \text{ kg}\right)\left(+1.5 \text{ m/s}\right)}{\left(70 \text{ kg}\right)} \\ &= -1.2 \text{ m/s} \end{aligned}$$

$\vec{v}_A = 0$

$\vec{v}\,'_A = +1.5 \text{m/s}$



4. Textbook question 12. a.:

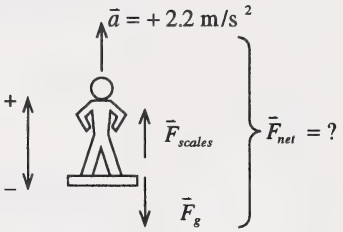
$$\vec{F}_{net} = \vec{F}_g + \vec{F}_{scales}$$
$$0 = -490\ \text{N} + \vec{F}_{scales}$$
$$\vec{F}_{scales} = 490\ \text{N}$$

Textbook question 12. b.:

By Newton's first law, the situation has zero net force. Therefore, the solution is identical to that for textbook question 12. a. $\left(\vec{F}_{scales} = 490\ \text{N}\right)$.

Textbook question 12. c.:

$$\vec{F}_{net} = \vec{F}_g + \vec{F}_{scales}$$
$$(50\ \text{kg})(-2.2\ \text{m/s}^2) = -490\ \text{N} + \vec{F}_{scales}$$
$$\vec{F}_{scales} = 3.8 \times 10^2\ \text{N}$$



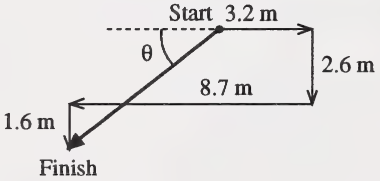
Section 3: Vectors

In this section vectors are introduced to represent displacement, velocity, acceleration, and force. Vectors are added using graphical and algebraic methods in one and two dimensions. Vector addition by resolving into horizontal and vertical components is emphasized. The independence of perpendicular components of vector quantities is noted. Forces in equilibrium are studied and the equilibrant is defined.

It's clear that vector addition by resolving into components is not designed for the weak math student. The strong math students will find challenges in the Enrichment section. An Outdoor Education teacher may serve as a resource because of knowledge of orienteering. Pilots or meteorologists would be wonderful guest speakers for discussing wind velocities in relation to air travel.

Section 3: Assignment Answer Key (37 marks)

1.
$$A^2 + B^2 = C^2$$
$$(4.2\ \text{m})^2 + (5.5\ \text{m})^2 = C^2$$
$$C = 6.9\ \text{m}$$

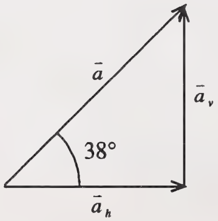


$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$\tan\theta = \frac{4.2}{5.5}$$
$$\theta = 37°$$

The ant's displacement is 6.9 m, W37°S.

2. a. $a_h = 22\ \text{m/s}^2\,(\cos 38°)$
$= 17\ \text{m/s}^2$

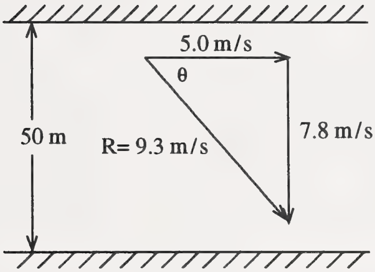
b. $a_v = 22\ \text{m/s}^2\,(\sin 38°)$
$= 14\ \text{m/s}^2$



3. a.

$$C^2 = A^2 + B^2$$
$$= (5.0\ \text{m/s})^2 + (7.8\ \text{m/s})^2$$
$$C = 9.3\ \text{m/s}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$\tan\theta = \frac{7.8}{5.0}$$
$$\theta = 57°$$



The boat moves 9.3 m/s, S33°E, or 9.3 m/s, E57°S.

b.

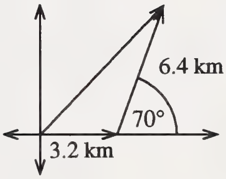
$$v = \frac{d}{t}$$
$$t = \frac{d}{v}$$
$$t = \frac{50\ \text{m}}{7.8\ \text{m/s}}$$
$$t = 6.4\ \text{s}$$

$$d = vt$$
$$= (5.0\ \text{m/s})(6.4\ \text{s})$$
$$= 32\ \text{m}$$

The boat will dock 32 m downstream.

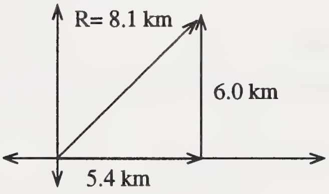
4. Find the *x*-components.

$$F_x = 6.4\ \text{km}(\cos 70°)$$
$$= 2.2\ \text{km}$$
$$F_x = 3.2\ \text{km}$$
$$F_{\text{net}\,x} = 5.4\ \text{km}$$



Find the *y*-components.

$$F_y = 6.4\ \text{km}(\sin 70°)$$
$$= 6.0\ \text{km}$$
$$F_y = 0\ \text{km}$$
$$F_{\text{net}\,y} = 6.0\ \text{km}$$



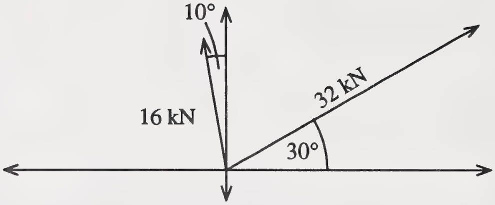
$$C^2 = A^2 + B^2$$
$$C^2 = (5.4\ \text{km})^2 + (6.0\ \text{km})^2$$
$$C = 8.1\ \text{km}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$\tan\theta = \frac{6.0}{5.4}$$
$$\theta = 48°$$

The hiker's displacement is 8.1 km, N42°E, or 8.1 km, E48°N.

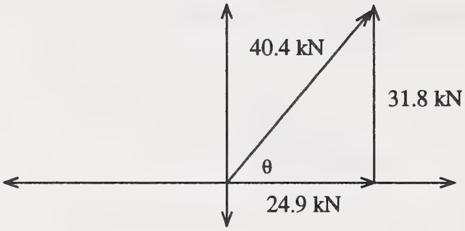
5. Find the x-components.

$$F_x = 32\text{ kN}\left(\cos 30^\circ\right)$$
$$= 27.7\text{ kN}$$
$$F_x = 16\text{ kN}\left(\cos 100^\circ\right)$$
$$= -2.8\text{ kN}$$
$$F_{net\,x} = 24.9\text{ kN}$$



Find the y-components.

$$F_y = 32\text{ kN}\left(\sin 30^\circ\right)$$
$$= 16\text{ kN}$$
$$F_y = 16\text{ kN}\left(\sin 100^\circ\right)$$
$$= 15.8\text{ kN}$$
$$F_{net\,y} = 31.8\text{ kN}$$



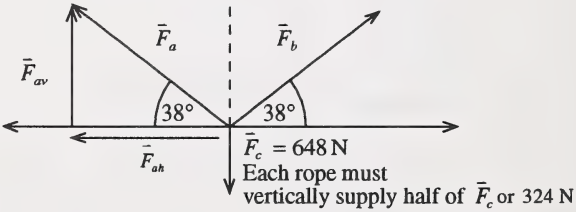
$$A^2 + B^2 = C^2$$
$$C^2 = \left(24.9\text{ kN}\right)^2 + \left(31.8\text{ kN}\right)^2$$
$$= 40.4\text{ kN}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{31.8\text{ kN}}{24.9\text{ kN}}$$
$$\theta = 51.9^\circ$$

The resultant of Tugboat A and Tugboat B is 40 kN at 52°. The equilibrant will be 40 kN at 232°, or 40 kN, W52°S, or 40 kN, S38°W.

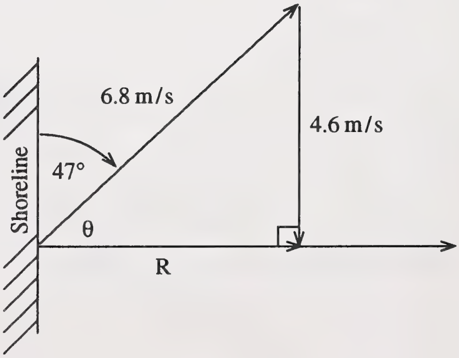
6. $$F_{av} = F_a\left(\sin 142^\circ\right)$$
$$324\text{ N} = F_a\left(\sin 142^\circ\right)$$
$$\frac{324\text{ N}}{\sin 142^\circ} = F_a$$
$$F_a = 526\text{ N}$$

The total force supplied by the ropes is 526 N or 5.3×10^2 N.


$\bar{F}_a$
$\bar{F}_b$
$\bar{F}_{av}$
38°
38°
$\bar{F}_{ah}$
$\bar{F}_c = 648\text{ N}$
Each rope must
vertically supply half of $\bar{F}_c$ or 324 N

7. $$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$
$$\sin\theta = \frac{4.6\text{ m/s}}{6.8\text{ m/s}}$$
$$\theta = 43^\circ$$

The driver should aim the boat N47°E or E43°N.



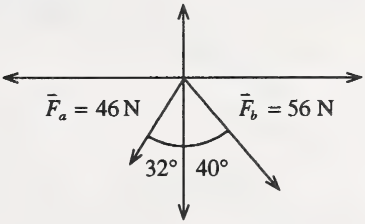
8. Relative to each other, the boats move together at 10 m/s.

$$t = \frac{d}{v} = \frac{662\text{ m}}{10\text{ m/s}} = 66\text{ s}$$

The boats meet in 66 s.

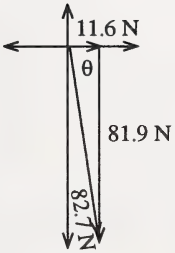
9. Find the *x*-components.

$$\begin{aligned} F_{ax} &= 46\text{ N}\left(\cos 238°\right) \\ &= -24.4\text{ N} \\ F_{bx} &= 56\text{ N}\left(\cos 310°\right) \\ &= 36\text{ N} \\ F_{net\,x} &= 36\text{ N} - 24.4\text{ N} \\ &= 11.6\text{ N} \end{aligned}$$



Find the *y*-components.

$$\begin{aligned} F_{ay} &= 46\text{ N}\left(\sin 238°\right) \\ &= -39\text{ N} \\ F_{by} &= 56\text{ N}\left(\sin 310°\right) \\ &= -42.9\text{ N} \\ F_{net\,y} &= -39\text{ N} - 42.9\text{ N} \\ &= -81.9\text{ N} \end{aligned}$$



Find the resultant.

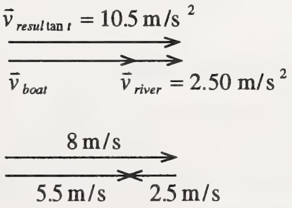
$$\begin{aligned} A^2 + B^2 &= C^2 \\ C^2 &= \left(11.6\text{ N}\right)^2 + \left(-81.9\text{ N}\right)^2 \\ C &= 82.7\text{ N} \end{aligned}$$

$$\begin{aligned} \tan\theta &= \frac{\text{opposite}}{\text{adjacent}} \\ \tan\theta &= \frac{81.9}{11.6} \\ \theta &= 81.9° \end{aligned}$$

The resultant is 83 N at 278°, or 83 N, E82°S, or 83 N, S8°E. The equilibrant must be the same magnitude in the opposite direction, which is 83 N at 98°, or 83 N, W82°N, or 83 N, N8°W.

10. $v_{ave} = \frac{\Delta d}{\Delta t}$

$$\begin{aligned} &= \frac{18\,900\text{ m}}{\left(30.0\text{ min}\right)\left(60\text{ s/min}\right)} \\ &= 10.5\text{ m/s} \end{aligned}$$



$\vec{v}_{resul\tan t} = 10.5\text{ m/s}^2$
$\vec{v}_{boat}$
$\vec{v}_{river} = 2.50\text{ m/s}^2$
8 m/s
5.5 m/s
2.5 m/s

The speed of the river is 2.50 m/s so the speed of the boat is 8.0 m/s.
The upstream speed of the boat would be 5.5 m/s.

$$v = \frac{d}{t}$$

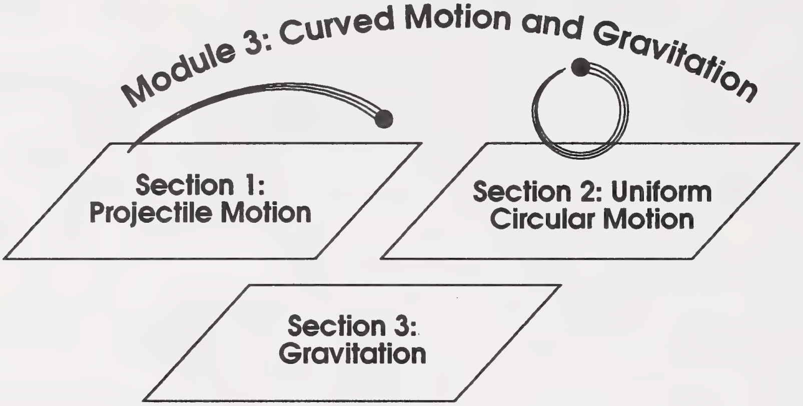
$$t = \frac{d}{v} = \frac{18\,900\text{ m}}{5.5\text{ m/s}}$$

$$t = 3436\text{ s} = 57.3\text{ min}$$

Module 3: Curved Motion and Gravitation

Overview

This module extends Newton's laws of motion (Module 2) and the description of motion (Module 1) to include motions that do not occur along a straight line. Projectile motion leads to circular motion, which in turn leads to gravitation and the motion of objects in the heavens. The concept of gravitational field is a subtle idea that students find challenging.


Module 3: Curved Motion and Gravitation
Section 1: Projectile Motion
Section 2: Uniform Circular Motion
Section 3: Gravitation

Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 3. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 1

Students will do **one** of the following investigations.

Part A

Investigation: Projectiles in Slow Motion

- the laser videodisc called *Physics: Cinema Classics*
- a laser videodisc player

Part B

Investigation: Projectile Pennies

- a horizontal tabletop
- two pennies

Section 1: Activity 2

Investigation: A Projectile Marble

- a large marble
- graph paper with 1-cm^2 squares
- a ruler with a grooved centre

- carbon paper
- a board with minimum dimensions of 30 cm × 30 cm
- books for support

Section 2: Activity 1

Investigation: Describing Circular Motion with Words

- a 15-cm long glass tube that is wrapped in a cardboard sleeve or masking tape. It should be fire polished at both ends.
- 1.5 m of nylon string or 20-lb. fishing line
- a two-hole size 4 rubber stopper
- twenty metal washers with a mass of 8.0 g each
- two paper clips
- a metre stick

If you use washers with different masses, you will need a balance to determine the mass of each washer.

If other people are in the room with the students while they are doing the lab, everyone should wear safety goggles.

Section 2: Activity 2

Investigation: Circular Motion of a Rubber Stopper

- a 15-cm long glass tube with a minimum outside diameter of 0.60 cm. It should be fire polished at both ends and wrapped in masking tape.
- nylon string or fishing line with a minimum length of 1.5 cm
- two-hole size 4 rubber stopper
- twenty metal washers with a mass of 8.0 g each
- two paper clips
- a stopwatch or clock with a second hand
- masking tape
- a metre stick or centimetre ruler

If you have access to a school laboratory, you may wish to substitute a known mass in place of the washers. If you use washers with different masses, you will need a balance to determine the mass of each washer.

If other people are in the room with the students while they are doing the lab, everyone should wear safety goggles.

Section 3: Enrichment

Investigation: Plants in Circular Motion

- an old record player with a 78 r/min speed
- three identical small glass jars
- six bean seeds
- paper towel
- epoxy glue
- an old long-play phonograph record
- a large cardboard box

The record and record player may be ruined by the end of this experiment. You will need to find an old record and record player for this investigation.

Additional Resources

- The same resources listed for Module 1 can provide additional support and information for teaching Module 3. Please refer to the list presented for Module 1.

- The book *Cosmos*, by Carl Sagan, published by Random House Canada Ltd., contains wonderfully interesting background information on the topic of planetary motion. Chapter 3: The Harmony of Worlds is particularly relevant. This book and this chapter are also available as a video series.

Possible Media

Videocassettes – *Mechanical Universe: #8 The Apple and the Moon* (California Institute of Technology)

Laser Videodisc – *Physics: Cinema Classics* (1993) – Available from D.C. Heath Canada Ltd. This set of three laser videodiscs has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on three assignments:

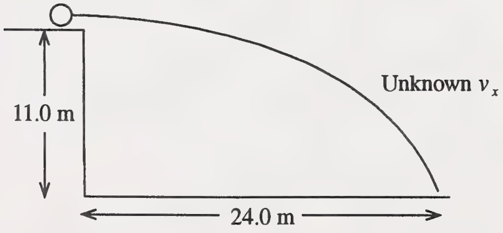
Section 1 Assignment	32%
Section 2 Assignment	32%
Section 3 Assignment	36%
TOTAL	100%

Section 1: Projectile Motion

Objects which are launched horizontally or at some angle above the horizontal are described in terms of two independent motions, namely a horizontal and vertical motion. The path followed by various objects, such as a soccerball which is kicked or a softball which is thrown, will be analysed in terms of these two independent motions.

Section 1: Assignment Answer Key (32 marks)

1.



Vertical Motion

$$\bar{y} = \bar{v}_y t + \frac{1}{2}\bar{g}t^2$$

$$t = \sqrt{\frac{-2\bar{y}}{\bar{g}}}$$

$$t = \sqrt{\frac{-2(-11.0\ \text{m})}{-9.80\ \text{m/s}^2}}$$

$$t = 1.50\ \text{s}$$

Horizontal Motion

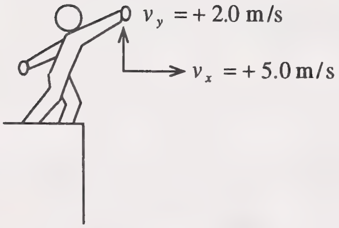
$$\bar{x} = \bar{v}_x t$$

$$\bar{v}_x = \frac{\bar{x}}{t}$$

$$\bar{v}_x = \frac{24.0\ \text{m}}{1.50\ \text{s}}$$

$$\bar{v}_x = 16.0\ \text{m/s}$$

2.



Horizontal velocity is constant at 5.0 m/s.

$$\bar{v}_x = 5.0\ \text{m/s}$$

Vertical velocity:

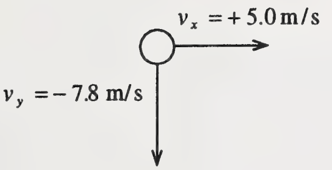
$$\bar{g} = \frac{\bar{v}_f - \bar{v}_i}{t}$$

$$\bar{v}_y = \bar{v}_{oy} - \bar{g}t$$

$$\bar{v}_y = 2.0\ \text{m/s} - 9.80\ \text{m/s}^2\ (1.0\ \text{s})$$

$$\bar{v}_y = -7.8\ \text{m/s}$$

Vector diagram:



3.

Vertical Motion

$$\vec{y} = \vec{v}_y t + \frac{1}{2}\vec{g}t^2$$

$$t = \sqrt{\frac{-2\vec{y}}{\vec{g}}}$$

$$t = \sqrt{\frac{2(-1500\ \text{m})}{-9.80\ \text{m/s}^2}}$$

$$t = 17.50\ \text{s}$$

Horizontal Motion

$$\vec{v}_x = (200\ \text{km/h})\left(\frac{1000\ \text{m}}{3600\ \text{h}}\right)$$

$$\vec{v}_x = 55.56\ \text{m/s}$$

$$\vec{x} = \vec{v}_x t$$

$$\vec{x} = (55.56\ \text{m/s})(17.50\ \text{s})$$

$$\vec{x} = 972\ \text{m}$$

4. a. To determine the horizontal velocity of the tennis ball, measure the horizontal distance between consecutive ball positions. Since the balls are separated horizontally by exactly two boxes, this means that they are separated by 0.80 m.

$$\vec{v}_x = \frac{\vec{x}}{t}$$

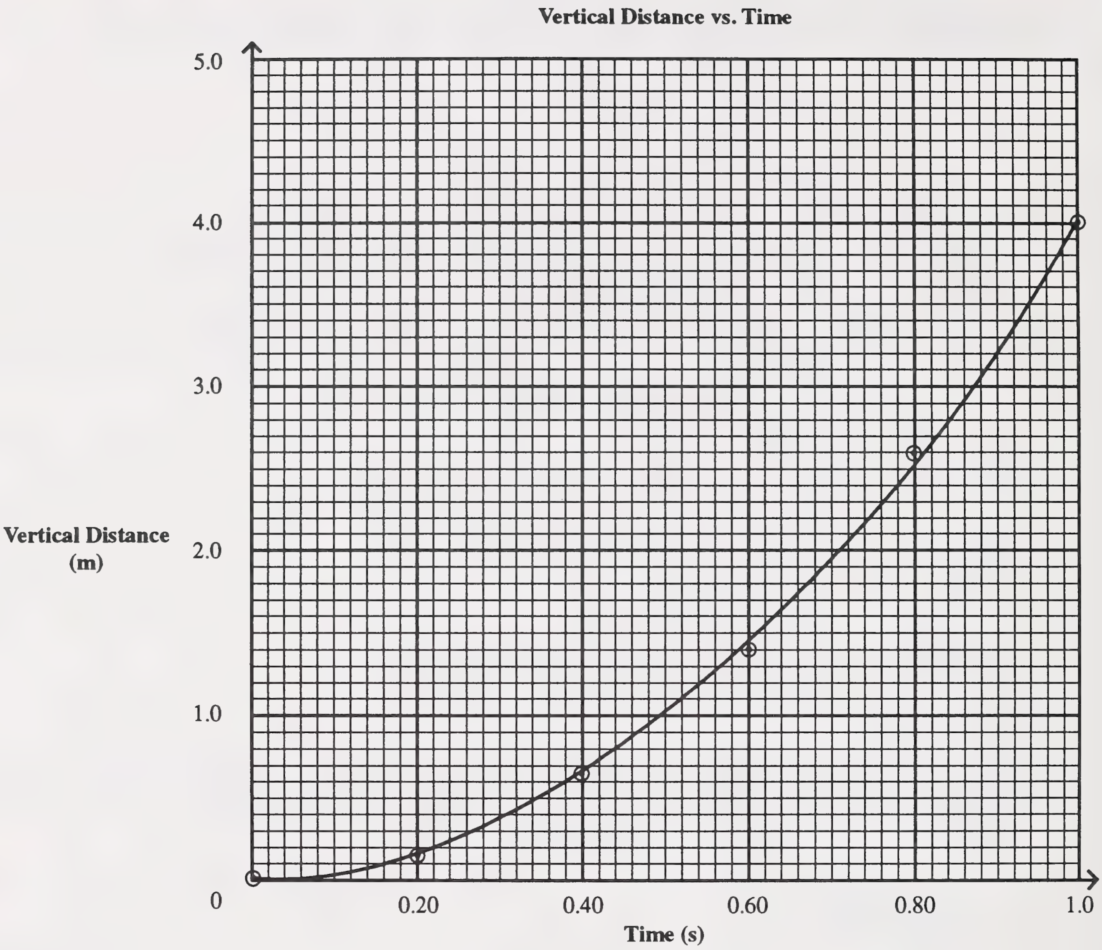
$$\vec{v}_x = \frac{0.80\ \text{m}}{1/5\ \text{s}} = \frac{0.80\ \text{m}}{0.20\ \text{s}}$$

$$\vec{v}_x = 4.0\ \text{m/s}$$

b.

Time (s)	Vertical Distance (m)
0	0
0.2	0.16
0.4	0.64
0.6	1.4
0.8	2.6
1.0	4.0

c.



d. Calculation of the vertical acceleration of the tennis ball:

$v_y = 0$

$t = 1.0 \text{ s}$

$\vec{y} = -4.00 \text{ m}$

$\vec{g} = ?$

$$\vec{y} = \vec{v}_y t + \frac{1}{2}\vec{g}t^2,\ \vec{v}_y = 0$$

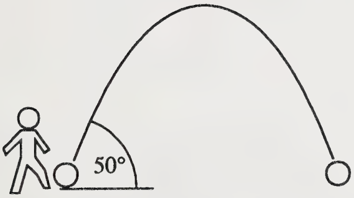
$$\vec{g} = \frac{-2\vec{y}}{t^2}$$

$$\vec{g} = \frac{2(-4.00 \text{ m})}{1.0 \text{ s}^2}$$

$$\vec{g} = -8.0 \text{ m/s}^2$$

A scalar approach would also be considered correct for this problem.

5.



$$\begin{aligned} v_x &= v_i(\cos\theta) \\ &= 20\ \text{m/s}(\cos 50°) \\ &= 20\ \text{m/s}(0.6428) \\ &= 12.9\ \text{m/s} \\ &= 13\ \text{m/s} \end{aligned}$$

$$\begin{aligned} v_y &= v_i(\sin\theta) \\ &= 20\ \text{m/s}(\sin 50°) \\ &= 20\ \text{m/s}(0.7660) \\ &= 15.3\ \text{m/s} \\ &= 15\ \text{m/s} \end{aligned}$$

To determine the range of the football, first determine the time in flight.

$$\vec{y} = \vec{v}_y t + \frac{1}{2}\vec{g}t^2$$

$$t = \frac{-2\vec{v}_y}{\vec{g}}$$

$$t = \frac{-2(15.3\ \text{m/s})}{-9.80\ \text{m/s}^2}$$

$$t = 3.12\ \text{s}$$

To determine range, use $\vec{x} = \vec{v}_x t$.

$$\vec{x} = (12.9\ \text{m/s})(3.12\ \text{s})$$

$$\vec{x} = 40.2\ \text{m}$$

The horizontal distance travelled by the football player can be calculated as follows.

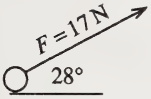
$$\vec{d} = \vec{v}t \text{ or } \vec{x} = (7.5\ \text{m/s})(3.12\ \text{s})$$

$$\vec{x} = 23.4\ \text{m}$$

Δx = distance the place kicker is from the ball when it lands

$\Delta x = 40.2\ \text{m} - 23.4\ \text{m} = 16.8\ \text{m}$

6.



$$F = ma$$

$$a = \frac{F}{m}$$

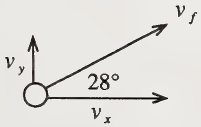
$$= \frac{17\ \text{N}}{0.34\ \text{kg}}$$

$$a = 50\ \text{m/s}^2$$

$$a = \frac{v_f - v_i}{t}$$

$$50\ \text{m/s}^2 = \frac{v_f - 0}{0.090}$$

$\vec{v}_f = 4.5\ \text{m/s}$ 28° above the horizontal

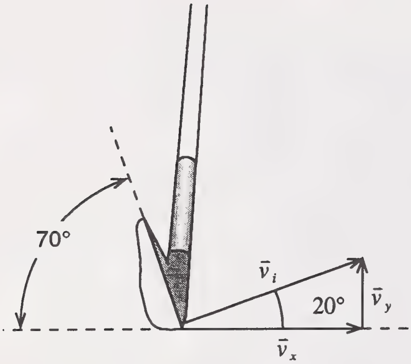


$$v_y = v_i(\sin\theta)$$

$$v_y = 4.5\ \text{m/s}(\sin 28°)$$

$$v_y = 2.1\ \text{m/s}$$

7.



The angle of the club face is not the angle that the ball would leave with respect to the horizontal. The force on the ball would be normal to the club face. Since $\vec{v}_x = \cos\theta \bullet \vec{v}_i$, Club A would give the ball the greatest horizontal component to its velocity. Clubs B and C would produce a larger angle θ and a smaller horizontal component.

Section 2: Uniform Circular Motion

Objects which travel in circular paths at constant speeds will experience an acceleration because their velocities are continually changing direction. This acceleration is described in terms of Newton's second law. The force and the acceleration can be calculated.

To introduce circular motion, ask students to give examples of objects which undergo circular motion and then lead them from this into the first activity.

Section 2: Assignment Answer Key (32 marks)

1. Calculate the maximum speed attained by the stone.

- Breaking strength equals F_c.

$$F_c = \frac{mv^2}{r}$$

$$v^2 = \frac{F_c r}{m} \quad \text{or} \quad v = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{450\ \text{N}(0.90\ \text{m})}{1.25\ \text{kg}}}$$

$$v = 18\ \text{m/s}$$

2. a. Calculate the speed of the rider.

$$r = \frac{1}{2}(4.8\ \text{m}) = 2.4\ \text{m}$$

$$T = 2.5\ \text{s}$$

$$v = \frac{2\pi r}{T}$$

$$v = \frac{2(\pi)2.4\ \text{m}}{(2.5\ \text{s})}$$

$$v = 6.03\ \text{m/s}$$

$$= 6.0\ \text{m/s}$$

b. Calculate the centripetal acceleration of the rider.

$$a_c = \frac{v^2}{r} = \frac{(6.03\ \text{m/s})^2}{2.4\ \text{m}}$$

$$a_c = 15.2\ \text{m/s}^2$$

$$= 15\ \text{m/s}^2$$

or

$$a_c = \frac{4\pi^2 r}{T^2}$$

$$= \frac{4\pi^2(2.4\ \text{m})}{(2.5\ \text{s})^2}$$

$$= 15.2\ \text{m/s}^2$$

$$= 15\ \text{m/s}^2$$

c. Calculate the coefficient of friction.

$F_f = \mu F_n$, where $F_n = F_c$ and $F_f = W = mg$.

$$\mu = \frac{F_f}{F_n} \qquad \mu = \frac{g}{a_c}$$

$$\mu = \frac{F_f}{F_c} = \frac{mg}{ma_c} = \frac{g}{a_c} \qquad = \frac{9.8\ \text{m/s}^2}{15.2\ \text{m/s}^2}$$

$$= 0.64$$

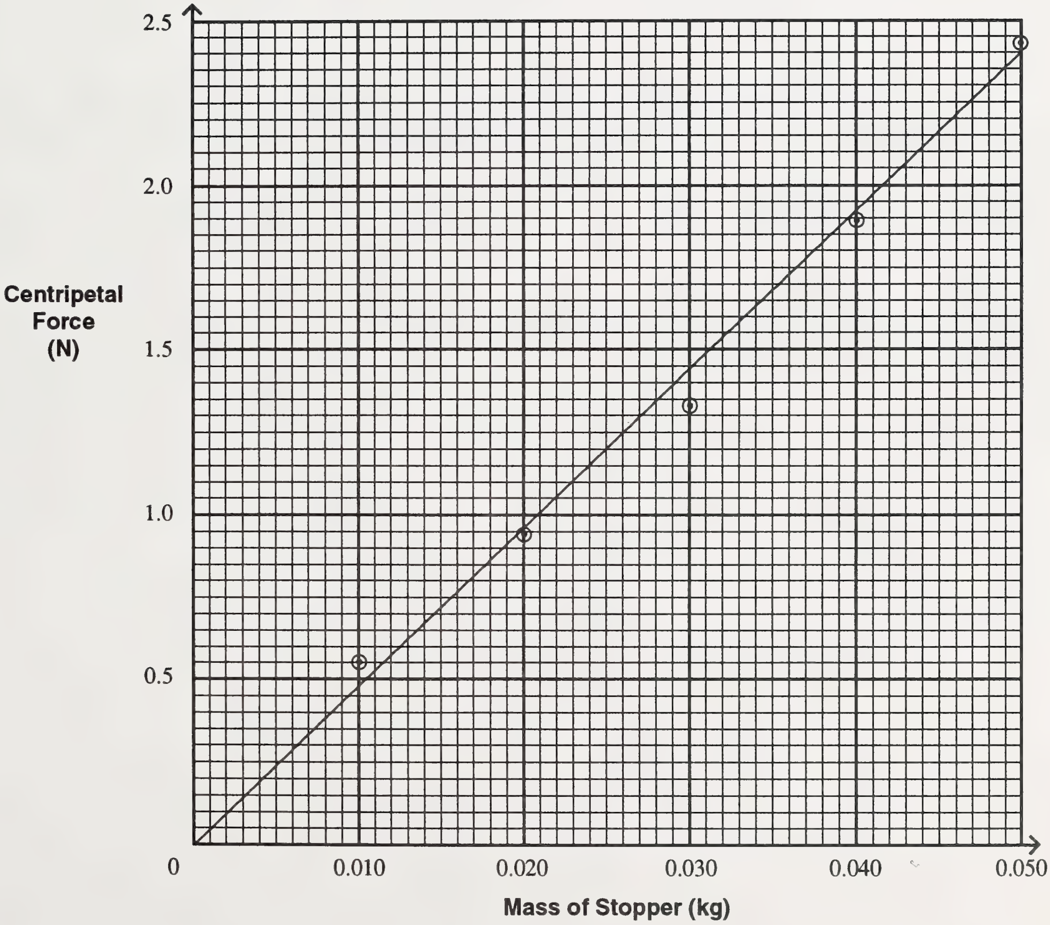
3. a. The controlled variables were the speed, the radius, and the period of rotation.

b. The manipulated variable was the mass of the stopper.

c. The responding variable was the number of washers (or the centripetal force).

d.

Mass of the Stopper vs. Centripetal Force



e. $$\begin{aligned}\text{slope} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{2.40\ \text{N} - 0\ \text{N}}{0.050\ \text{kg} - 0\ \text{kg}}\\ &= 48\ \text{N/kg}\end{aligned}$$

f.

$$\begin{tikzcd}
\boxed{\text{slope} = \frac{\text{rise}}{\text{run}}} \arrow[d] & & \boxed{F_c = \frac{mv^2}{r}} \arrow[d] \\
\boxed{\text{slope} = \frac{F_c}{m}} \arrow[dr] & & \boxed{\frac{F_c}{m} = \frac{v^2}{r}} \arrow[dl] \\
& \boxed{\text{slope} = \frac{v^2}{r}} &
\end{tikzcd}$$

The slope represents the ratio of v^2/r, which is the centripetal acceleration.

g. Theoretical value:

$$a_c = \frac{v^2}{r} = \frac{(4.19\ \text{m/s})^2}{0.40\ \text{m}} = 44\ \text{m/s}^2$$

Experimental value:

$$a_c = \text{slope} = 48\ \text{N/kg} = \frac{48\ \cancel{\text{kg}}\ \text{m/s}^2}{\cancel{\text{kg}}} = 48\ \text{m/s}^2$$

$$\text{Percent error} = \frac{\left|48\ \text{m/s}^2 - 44\ \text{m/s}^2\right|}{44\ \text{m/s}^2} \times 100\% = 9.1\%$$

4. a. $d = 94$ m

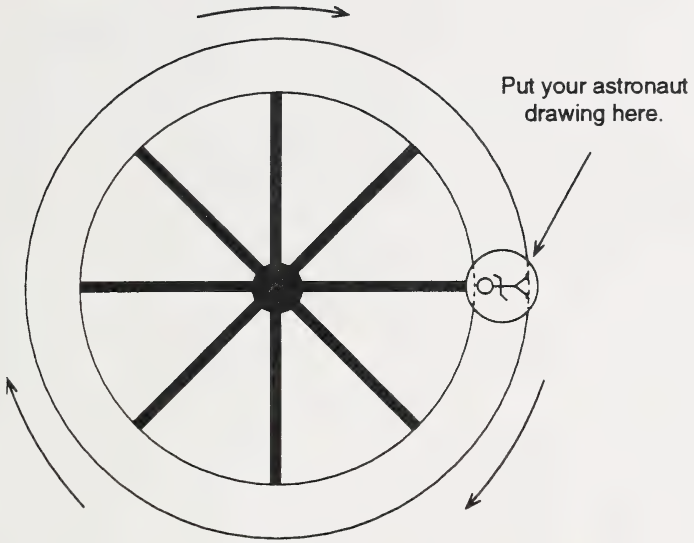
$r = 47$ m

$T = ?$

$a_c = g = 9.80\ \text{m/s}^2$

$$\begin{aligned}a_c &= \frac{4\pi^2 r}{T^2}\\ T^2 &= \frac{4\pi^2 r}{a_c}\\ T &= \sqrt{\frac{4\pi^2 r}{a_c}}\\ &= \sqrt{\frac{4(\pi^2)(47\ \text{m})}{9.80\ \text{m/s}^2}}\\ &= \sqrt{189.3\ \text{s}^2}\\ &= 13.8\ \text{s}\\ &= 14\ \text{s}\end{aligned}$$

b.



c. According to Newton's first law, the astronauts have a tendency to maintain their velocity. The outer rim of the space station prevents them from doing this by supplying a centripetal force to the centre of the space station. From the lab frame of reference, the astronauts are prevented from flying off in a straight line because the centripetal force keeps turning their velocity.

d. From the rotating frame of reference, a centrifugal force appears to be causing objects to be pushed to the outer rim of the space station.

Section 3: Gravitation

Planets, satellites, and other orbiting bodies travel in circular paths around some central mass. The moon travels in an almost circular path around the earth, the earth travels in a nearly circular path around the sun. The laws developed by Kepler and Newton are used to describe the motions of such bodies. Orbital speed and period can be calculated. The gravitational force which exists between any two masses can be determined and the concept of gravitational field is described.

Students should realize that the gravitational force is relatively small unless large masses are used.

Section 3: Assignment Answer Key (36 marks)

1. $r_a = r_{earth} + 2.0 \times 10^5 \text{ m}$

$$r_a = \left(6.37 \times 10^6 \text{ m}\right) + \left(2.0 \times 10^5 \text{ m}\right)$$

$$r_a = 6.57 \times 10^6 \text{ m}$$

$$\left(\frac{T_a}{T_b}\right)^2 = \left(\frac{r_a}{r_b}\right)^3$$

$$r_b{}^3 = r_a{}^3 \left(\frac{T_b}{T_a}\right)^2$$

$$r_b{}^3 = \left(6.57 \times 10^6 \text{ m}\right)^3 \left(\frac{6.0 \text{ h}}{1.4 \text{ h}}\right)^2$$

$$r_b{}^3 = \left(2.84 \times 10^{20} \text{ m}^3\right)\left(\frac{36 \text{ h}^2}{1.96 \text{ h}^2}\right)$$

$$r_b{}^3 = \left(2.84 \times 10^{20} \text{ m}^3\right)(18.37)$$

$$\sqrt[3]{r_b{}^3} = \sqrt[3]{5.2096 \times 10^{21} \text{ m}^3}$$

$$r_b = 1.734 \times 10^7 \text{ m}$$

$$\text{height} = r_b - r_e$$

$$\text{height} = 1.734 \times 10^7 \text{ m} - 6.37 \times 10^6 \text{ m}$$

$$\text{height} = 1.1 \times 10^7 \text{ m}$$

2.

$$F_g = F_c$$

$$\frac{G m_e \cancel{m}}{r^2} = \frac{\cancel{m}\, 4\pi^2 r}{T^2}$$

$$m_e = \frac{4\pi^2 r^3}{GT^2} \quad \left(T = 27.4 \text{ days} = 2.37 \times 10^6 \text{ s}\right)$$

$$m_e = \frac{4(3.14)^2 \left(3.85 \times 10^8 \text{ m}\right)^3}{\left(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2\right)\left(2.37 \times 10^6 \text{ s}\right)^2}$$

$$m_e = \frac{2.25 \times 10^{27} \text{ m}^3}{371 \text{ N m}^2\text{s}^2/\text{kg}^2}$$

$$m_e = 6.00 \times 10^{24} \text{ kg}$$

3.

$$W = F_g = 882 \text{ N}$$

$$F_g \propto m_1 m_2$$

$$F_g = 882 \text{ N} \times 95.3$$

$$F_g = 8.40 \times 10^4 \text{ N}$$

$$F_g \propto \frac{1}{r^2}$$

$$F_g \propto \frac{1}{(8.9)^2}$$

$$F_g \propto \frac{1}{79.2}$$

$$F_g \propto \left(8.40 \times 10^4 \text{ N}\right)\left(\frac{1}{79.2}\right)$$

$$F_g = 1060 \text{ N} = 1.06 \times 10^3 \text{ N}$$

4.

$$F_g = \frac{G m_1 m_2}{r^2}$$

$$F_g = \frac{\left(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2\right)(65 \text{ kg})(74 \text{ kg})}{(3.0 \text{ m})^2}$$

$$F_g = \frac{3.21 \times 10^{-7} \text{ N m}^2/\text{kg}^2 \text{ kg}^2}{9.0 \text{ m}^2}$$

$$F_g = 3.6 \times 10^{-8} \text{ N}$$

5. The rate at which the area is swept out is determined by $\frac{\pi r^2}{T}$.

$$\text{rate} = \frac{3.14\left(3.9 \times 10^8 \text{ m}\right)^2}{27.3 \text{ days}}$$

$$= 1.7 \times 10^{16} \text{ m}^2/\text{day}$$

6. a. Calculate Jupiter's acceleration due to gravity.

$$g = \frac{G m_1}{r^2}$$

$$g = \frac{\left(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2\right)\left(1.90 \times 10^{27} \text{ kg}\right)}{\left(6.91 \times 10^7 \text{ m}\right)^2}$$

$$g = 26.5 \text{ m/s}^2$$

b. $9.8\ \text{m/s}^2 \times \text{factor} = 26.5\ \text{m/s}^2$
$\text{factor} = 2.7$

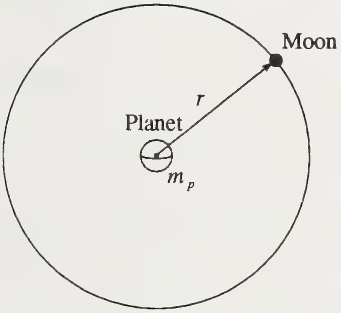
Jupiter's acceleration due to gravity is 2.7 times that of Earth's.

7. $$g = \frac{Gm_1}{r^2}$$
$$g \propto \frac{m_1}{r^2}$$
$$g \propto \frac{3m_1}{(2r)^2}$$
$$g \propto \frac{3m_1}{4r^2}$$
$$g = 9.80\ \text{m/s}^2 \times \frac{3}{4}$$
$$g = 7.35\ \text{m/s}^2$$

8. $$W = mg$$
$$g = \frac{W}{m}$$
$$= \frac{935\ \text{N}}{250\ \text{kg}}$$
$$= 3.74\ \text{N/kg}$$

9. The mass m_1 is more massive because it bends space more than m_2.

10. a.

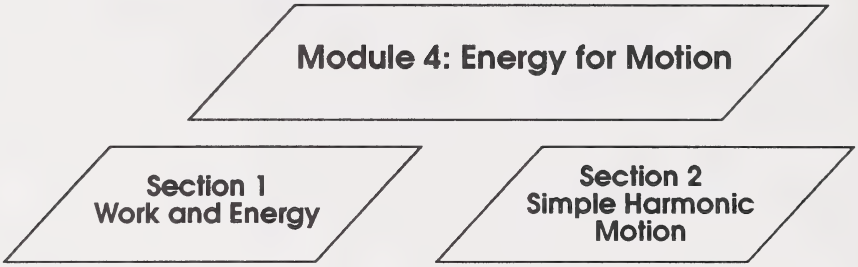


b. $$F_g = F_c$$
$$\frac{Gm_p\cancel{m}}{r^2} = \frac{\cancel{m}\,4\pi^2 r}{T^2}$$
$$T^2 = \frac{4\pi^2 r \bullet r^2}{Gm_p}$$
$$T^2 = \frac{4\pi^2 r^3}{Gm_p}$$
$$T = \sqrt{\frac{4\pi^2 r^3}{Gm_p}}$$

Module 4: Energy for Motion

Overview

The emphasis of this module is on the way in which physics defines and manipulates the concept of work and energy. Students are led to understand that all physical processes depend on the transfer of energy, and are asked to perform experiments and solve problems related to specific transfers of energy. The relation of energy transfer and simple harmonic motion is examined.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 4. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 4

Investigation: Investigating Energy

Students will do **either** Part A **or** Part B.

Part A

- 500-g mass
- ticker tape
- ticker tape timer
- string
- metre stick
- ring stand
- ring clamp or test tube clamp
- masking tape

Part B

- scissors
- tape

Section 2: Activity 1

Investigation: Determining the Period of a Pendulum

- two chairs
- broomstick
- 50 cm of string
- 500-g mass or a 1-L milk carton half-filled with water
- stopwatch
- protractor

Section 2: Activity 2

Investigation: The Restoring Force for a Pendulum

- protractor
- ruler

Investigation: Verification of the Equation for the Period of a Pendulum

In this investigation students must design and carry out their own experiment. There is no standard list of materials. The following list is typical of what students may request.

- stopwatch
- pendulum bob (500-g mass)
- string
- support stand

Section 2: Enrichment

- retort stand and base
- stopwatch
- weight set
- a spring
- utility clamps and C-clamps
- metre stick

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 4. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Harmonic Motion*, VEC/Criterion Video (Available through ACCESS Network). This is a very good program that your students should not miss.

Laser Videodisc – *Physics: Cinema Classics* (1993) – Available from D.C. Heath Canada Ltd. This set of three laser videodiscs has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	37%
Section 2 Assignment	63%
TOTAL	100%

Section 1: Work and Energy

The emphasis in this section is on the specific definitions of *work* and *energy* used in physics. This section is a review of key ideas from Science 10. Students should understand how work and energy relate to each other and the universe. It is necessary for students to realize that for work to be done, there must be a component of the applied force acting in the direction of the motion created. This concept will create some confusion at first, so be careful to have students analyse the applied force carefully.

Section 1: Assignment Answer Key (37 marks)

1. The answer will depend on the justification.

   a. TRUE – No work is done on the object.

      FALSE – Work is done within the muscles of your arms.

   b. FALSE – The shuttle is accelerating, but no work is done because the motion is always at right angles to the force applied, and so there is no component of force in the direction of motion.

2. $$\begin{aligned} W &= F_1 d_1 + F_2 d_2 \\ &= (80.0\ \text{N})(3.00\ \text{m}) + (40.0\ \text{kg})(9.80\ \text{m/s}^2)(1.00\ \text{m}) \\ &= 632\ \text{J} \end{aligned}$$

3. $$\begin{aligned} W &= F(\cos\theta)d \\ &= (320\ \text{N})(\cos 30°)(10.0\ \text{m}) \\ &= 2.77\times10^3\ \text{J} \end{aligned}$$

4. $$\begin{aligned} W &= \text{area beneath line} \\ &= \text{Area 1} + \text{Area 2} \\ &= bh + \frac{1}{2}bh \\ &= (0.10\ \text{m})(120\ \text{N}) + \frac{1}{2}(0.10\ \text{m})(60\ \text{N}) \\ &= 15\ \text{J} \end{aligned}$$

5. $$P = \frac{W}{t} = \frac{Fd}{t}$$

   so

   $$t = \frac{Fd}{P} = \frac{mgd}{P} = \frac{(1.30\times10^3\ \text{kg})(9.80\ \text{m/s}^2)(30.0\ \text{m})}{4.20\times10^3\ \text{W}} = 91.0\ \text{s}$$

6. $$E_k = \frac{1}{2}mv^2 \text{ so } v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2(6.20\times10^{12}\ \text{J})}{45\times10^3\ \text{kg}}} = 1.66\times10^4\ \text{m/s}$$

7. $$\begin{aligned} E_p &= mgh \\ &= (0.30\ \text{kg})(9.81\ \text{m/s}^2)(120\ \text{m}) \\ &= 353\ \text{J} \end{aligned}$$

8. a. $\cos\theta = \dfrac{\text{adjacent}}{\text{hypotenuse}}$

$$\cos 10^\circ = \frac{x}{2.00\text{ m}}$$

$$x = 2.00\text{ m}\left(\cos 10.000^\circ\right)$$

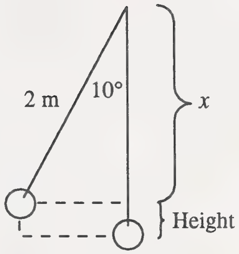
$$x = 1.9696\text{ m}$$

$$\text{height} = 2.0000\text{ m} - 1.9696\text{ m}$$

$$= 0.0304\text{ m}$$

$$= 3.04\text{ cm}$$

This diagram is not drawn to scale.



b. $E_p = mgh = \left(0.500\text{ kg}\right)\left(9.80\text{ m/s}^2\right)\left(0.0304\text{ m}\right) = 0.149\text{ J}$

c. $\Delta E_p = E_k$

$$0.149\text{ J} = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2\left(0.149\text{ J}\right)}{0.500\text{ kg}}}$$

$$v = 0.772\text{ m/s}$$

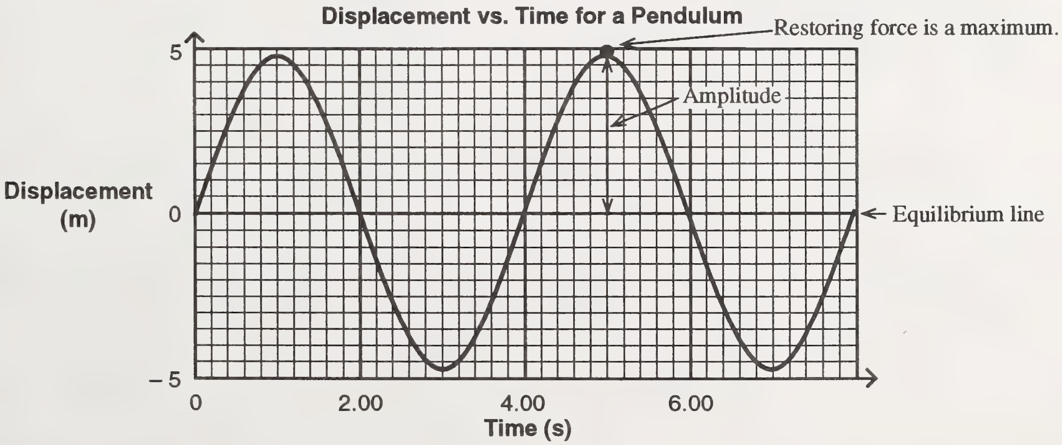
Section 2: Simple Harmonic Motion

The emphasis in this section is on the way in which energy transfer occurs for objects exhibiting a simple periodic motion – in this case harmonic motion. Students should realize that for objects to exhibit harmonic motion, there must be a restoring force which causes acceleration towards a stable equilibrium point, at which the object will come to rest over time. Towards the end of the section, the tendency of objects to come to rest at the equilibrium point will be addressed.

It is valuable to point out to students that the difference between circular motion and linear motion for a simple harmonic oscillator is very slight. For objects undergoing harmonic motion, there will be a tendency for the oscillating mass to switch between a linear and circular motion.

Section 2 Assignment (63 marks)

1. a.



b. period = time to complete 1 cycle
$= 4.00 \text{ s}$

c. $T = 2\pi\sqrt{\frac{l}{g}}$ so $T^2 = 4\pi^2\left(\frac{l}{g}\right)$ so $l = \frac{gT^2}{4\pi^2} = \frac{(9.80 \text{ m/s}^2)(4.00 \text{ s})^2}{4(3.14)^2} = 3.97 \text{ m}$

2. a. Pole

$$g = \frac{Gm_1}{r^2}$$
$$= \frac{(6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2)(5.979 \times 10^{24} \text{ kg})}{(6.370 \times 10^6 \text{ m})^2}$$
$$= 9.828 \text{ N/kg}$$
$$= 9.83 \text{ m/s}^2$$

b. Equator

- Step 1: Find the gravitational field.

$$g = \frac{Gm_1}{r^2}$$
$$= \frac{(6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2)(5.979 \times 10^{24} \text{ kg})}{(6.391 \times 10^6 \text{ m})^2}$$
$$= 9.764 \text{ N/kg}$$
$$= 9.76 \text{ m/s}^2$$

- Step 2: Find the centripetal acceleration using $T = 24 \text{ h} = 8.64 \times 10^4 \text{ s}$.

$$a_c = \frac{4\pi^2 r}{T^2}$$
$$= \frac{4(\pi)^2(6.391 \times 10^6 \text{ m})}{(8.64 \times 10^4 \text{ s})^2}$$
$$= 0.034 \text{ m/s}^2$$

- Step 3: Find the net acceleration.

$$\begin{array}{r} 9.764 \text{ m/s}^2 \\ -0.034 \text{ m/s}^2 \\ \hline 9.73 \text{ m/s}^2 \end{array}$$

c. $$T = 2\pi\sqrt{\frac{l}{g}}$$
$$= 2\pi\sqrt{\frac{1.00 \text{ m}}{9.83 \text{ m/s}^2}}$$
$$= 2.004 \text{ s}$$

$$\text{number of swings} = \frac{8.00 \text{ min}}{2.004 \text{ s}}$$
$$= \frac{480 \text{ s}}{2.004 \text{ s}}$$
$$= 239.5 \text{ swings}$$
$$= 240 \text{ swings}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$
$$= 2\pi\sqrt{\frac{1.00 \text{ m}}{9.73 \text{ m/s}^2}}$$
$$= 2.014 \text{ s}$$

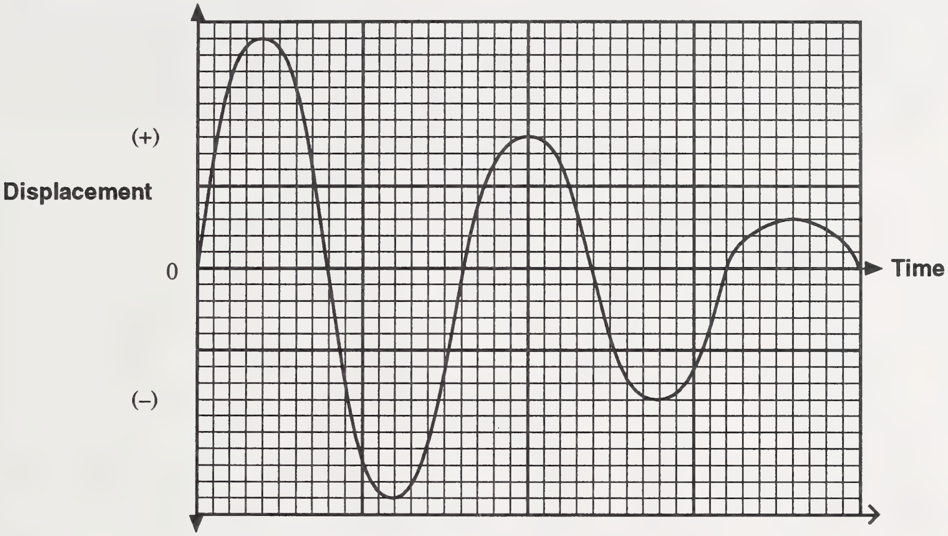
$$\text{number of swings} = \frac{8.00 \text{ min}}{2.014 \text{ s}}$$
$$= \frac{480 \text{ s}}{2.014 \text{ s}}$$
$$= 238.3 \text{ swings}$$
$$= 238 \text{ swings}$$

The pendulum at the pole makes about one more swing than the pendulum at the equator. This question can also be answered with a ratio and proportion argument applied to the equation. This is a difficult question. Students should be given many opportunities for part marks in part b.

3. The length of the pendulum determines the period of the pendulum. The length is measured to the centre of mass of the pendulum bob. As liquid drains out of the coconut, the centre of mass changes to the lower portion of the coconut, increasing the length of the pendulum, and thus increasing the period. As the last of the liquid leaves, the centre of mass moves to the middle of the coconut, decreasing the length of the pendulum, and decreasing the period.

4. a. The force of gravity provides a restoring force towards the bottom of the gully, which is the equilibrium position. As the skateboarder moves away from the bottom, the force of gravity causes a deceleration to stop the skateboarder and an acceleration to move the skateboarder back to the bottom. The skateboard overshoots the bottom and rises on the opposite side only to begin the whole process again.

b.



c. Oscillatory (harmonic) motion cannot occur since there is no restoring force acting opposite to the displacement. All forces (i.e., gravity) cause motion towards the bottom of the hill, which is in the same direction as the displacement.

5. $$T = \frac{\text{number of seconds}}{\text{oscillation}}$$

$$= \frac{(4.00\ \text{min})(60\ \text{s/min})}{84.5}$$

$$= 2.84\ \text{s}$$

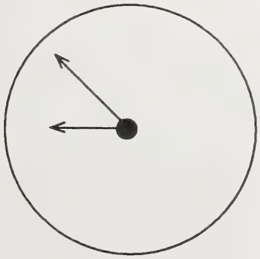
$$T = 2\pi\sqrt{\frac{l}{g}}$$

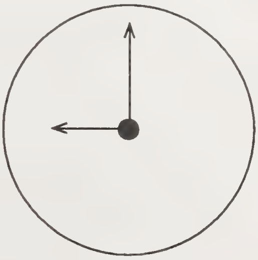
$$g = \frac{4\pi^2 l}{T^2}$$

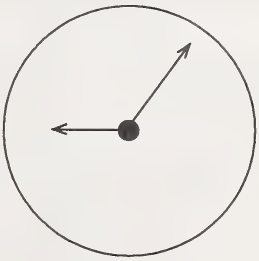
$$= \frac{4\pi^2(2.00\ \text{m})}{(2.84\ \text{s})^2}$$

$$= 9.79\ \text{m/s}^2$$

6. Hot objects expand, so the length of the pendulum would increase. An increase in the length of the pendulum would correspond to an increase in the period. Increased period means the clock runs slower, so the hands of the clock at the higher temperature should be slow. The reverse reasoning would apply to the cold clock.


Clock in
a hot room

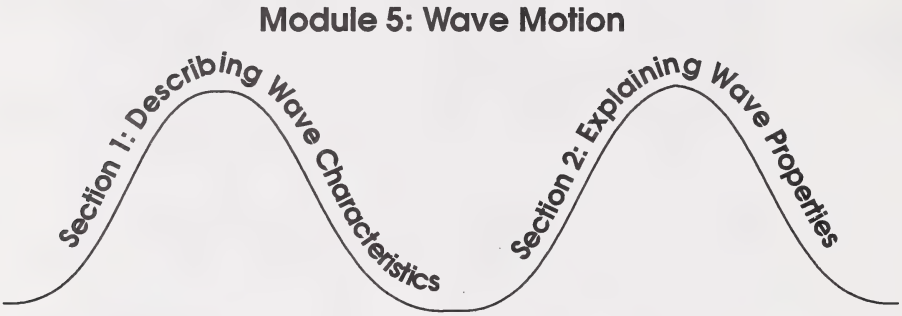

Clock at
room temperature


Clock in
a cold room

Module 5: Wave Motion

Overview

The emphasis of this module is for the student to develop a wave theory basis that will eventually be applied to light in the next two modules. This module extends the ideas of energy and simple harmonic motion to waves. The key is for the student to realize that wave theory applies to all waves. In Section 1 the student will learn how waves are measured and defined. The second section describes common wave properties. In both sections, all of the wave theory developed is applied to sound waves. It is important that the students do the activities to get a concrete knowledge of waves and their behaviour.


Module 5: Wave Motion
Section 1: Describing Wave Characteristics
Section 2: Explaining Wave Properties

Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 5. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 1

Investigation: Observing Waves

- thick string or twine
- masking tape
- a long coil spring
- a chair
- an area of empty floor space that is about 1 m × 5 m

Section 1: Activity 2

Investigation: Connections Between Wavelength and Frequency

- a metre stick
- a stopwatch
- a spring with a diameter less than 3 cm
- a piece of masking tape
- strong string or twine
- a chair
- a partner to help count the number of vibrations

Section 1: Activity 4

Investigation: Singing Glasses

- a small saucer with 50 mL of vinegar
- a quiet room
- three different shapes of drinking glasses

All the glasses should be made of glass or crystal and they should not have handles. Ideally, thin-walled glasses with stems work best, such as wine goblets or brandy snifters.

Section 2: Activity 1

Investigation: Reflection from a Fixed End

- a long coil spring
- a chair
- heavy string or twine
- an area of floor space that is approximately 5 m by 1 m

Investigation: Reflection from a nearly Free End

- a long coil spring
- 2 m of heavy string or twine
- a floor area that is about 5 m by 1 m

Section 2: Activity 3

Investigation: What Happens When Waves Meet?

- a long coil spring
- an area of floor space that is about 1 m × 5 m
- a partner

Section 2: Activity 3

Investigation: Interference from a Tuning Fork

- a tuning fork
- a rubber mallet or the soft sole of an athletic shoe

Section 2: Activity 4

Investigation: Measuring the Speed of Sound

- a tuning fork with a known frequency
- a deep bucket filled with water
- a length of plastic pipe or tubing
- a metre stick
- a rubber mallet or soft soled athletic shoe

Section 2: Enrichment

Building Your Own Wind Chimes

- 2.1 m of 12.7-mm copper tubing (known as half-inch tubing)
- hacksaw or pipe cutter
- drill with high-speed bits
- metal file
- nylon fishing line
- 30-cm^2 sheet of Plexiglas™ (or substitute 1/4-inch plywood)

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 5. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Properties of Waves - Non Light*, Classroom Video (Available through ACCESS Network)
– *The Physics of Music*, Classroom Video (Available through ACCESS Network)

Both of these programs are excellent resources that will add to the students' understanding and enthusiasm for the module.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	39%
Section 2 Assignment	61%
TOTAL	100%

Section 1: Describing Wave Characteristics

This section introduces students to the terminology and definitions of the characteristics of waves. It is essential that the students know the meaning of terms like *wavelength*, *frequency*, and *amplitude* because these ideas will be used extensively throughout the next two modules. Experience seems to indicate that the best way for students to learn these ideas is for them to measure these quantities while doing investigations.

Section 1: Assignment Answer Key (39 marks)

1. $f = 120\ 000\ \text{Hz}$

$v = 343\ \text{m/s}$

$\lambda = ?$

$$v = \lambda f$$

$$\lambda = \frac{v}{f}$$

$$= \frac{343\ \text{m/s}}{120\ 000\ \text{Hz}}$$

$$= 2.86 \times 10^{-3}\ \text{m}$$

2. Textbook question 3:

The steel rails allow the sound from the train to travel in only two directions, so more of the sound energy is sent to the listener. When the sound travels through the air, it spreads out in three dimensions from the train.

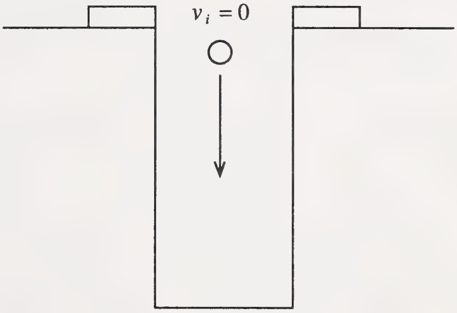
The steel rails allow sounds to travel at 5790 m/s, which is much faster than the speed in air. A listener would receive the sound sooner if they listened to the steel rails.

3. Textbook question 3:

Sound waves need a medium. Since there is no medium in space, it is impossible for sound to travel trom one spaceship to the other. The producer should rewrite this scene.

4. Textbook question 6:

Step 1: Find the time to reach the bottom.



$$
\begin{aligned}
d &= \frac{1}{2}gt^2 + v_i t \\
d &= \frac{1}{2}gt^2 \\
t^2 &= \frac{2d}{g} \\
t &= \sqrt{\frac{2d}{g}} \\
&= \sqrt{\frac{2(122.5\text{ m})}{9.80\text{ m/s}^2}} \\
&= \sqrt{25.0\text{ s}^2} \\
&= 5.00\text{ s}
\end{aligned}
$$

Step 2: Find the time for the sound to reach the top.

$v = 343\text{ m/s}$

$d = 122.5\text{ m}$

$t = ?$

$$
\begin{aligned}
v &= \frac{d}{t} \\
t &= \frac{d}{v} \\
&= \frac{122.5\text{ m}}{343\text{ m/s}} \\
&= 0.357\text{ s}
\end{aligned}
$$

Step 3: Find the total time.

$$
\begin{array}{r}
5.00\text{ s} \\
+\,0.357\text{ s} \\
\hline
5.36\text{ s}
\end{array}
$$

Textbook question 10:

$$\begin{aligned} f &= 4.25\ \text{MHz} \\ &= 4.25 \times 10^{6}\ \text{Hz} \\ v &= 1.50\ \text{km/s} \\ &= 1.50 \times 10^{3}\ \text{m/s} \\ \lambda &= ? \end{aligned}$$

$$\begin{aligned} v &= \lambda f \\ \lambda &= \frac{v}{f} \\ &= \frac{1.50 \times 10^{3}\ \text{m/s}}{4.25 \times 10^{6}\ \text{m/s}} \\ &= 3.53 \times 10^{-4}\ \text{m} \end{aligned}$$

5. Textbook question 5.a.:

The reflection from a large insect would be more intense because more of the wave would reflect from a larger body.

Textbook question 5.b.:

An insect that is flying towards the bat would return an echo with a higher frequency than an insect that is flying away from the bat. This is due to the Doppler effect.

6. $f = 512\ \text{Hz}$ $\quad$ $T = \frac{1}{f} = \frac{1}{512\ \text{Hz}} = 1.95 \times 10^{-3}\ \text{s}$

$T = ?$

7. a. $f = \dfrac{192\ \text{cycles}}{1.50\ \text{s}} = 128\ \text{Hz}$

b. $T = \dfrac{1.50\ \text{s}}{192\ \text{cycles}} = 7.81 \times 10^{-3}\ \text{s}$ or $T = \dfrac{1}{f} = \dfrac{1}{128\ \text{Hz}} = 7.81 \times 10^{-3}\ \text{s}$

8. a. Crests occur at points B and F.

b. Troughs occur at points D and H.

c. Point G is one wavelength from point C.

d. Point D is one-half wavelength from point B.

e. The wavelength is 20.0 squares or 200 cm.

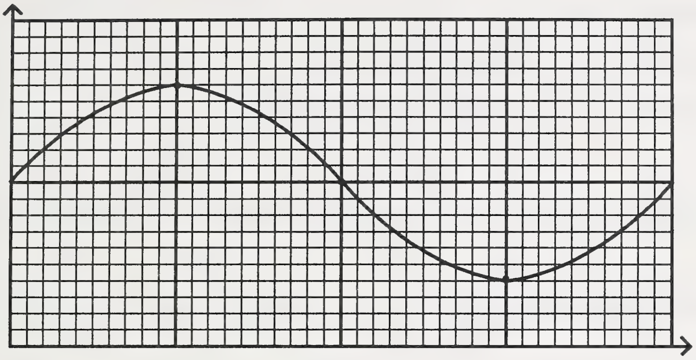
f. The amplitute is 6.0 squares or 60 cm.

g. $f = 40\ \text{Hz}$ $\quad$ $v = \lambda f$

$\lambda = 200\ \text{cm}$ $\quad$ $= (2.00\ \text{m})(40\ \text{Hz})$

$= 2.00\ \text{m}$ $\quad$ $= 80\ \text{m/s}$

h.



Halving the frequency doubles the wavelength. The amplitude should be unchanged.

9. Textbook question 4.a.:

$d = 4.4\ \text{m}$

$t = 1.8\ \text{s}$

$v = ?$

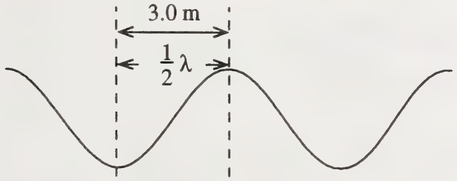
$T = 1.2\ \text{s}$

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{4.4\ \text{m}}{1.8\ \text{s}} \\ &= 2.\overline{4}\ \text{m/s} \end{aligned}$$

Textbook question 4.b.:

$$\begin{aligned} v &= \lambda f \\ &= \frac{\lambda}{T} \\ \lambda &= vT \\ &= \left(2.\overline{4}\ \text{m/s}\right)\left(1.2\ \text{s}\right) \\ &= 2.9\ \text{m} \end{aligned}$$

Textbook question 6:



Step 1: Find the wavelength.

$$\lambda = 6.0\ \text{m}$$

Step 2: Find the frequency.

$$f = \frac{14\ \text{cycles}}{20\ \text{s}} = 0.70\ \text{Hz}$$

Step 3: Find the speed.

$$\begin{aligned} v &= \lambda f \\ &= (6.0\ \text{m})(0.70\ \text{Hz}) \\ &= 4.2\ \text{m/s} \end{aligned}$$

Section 2: Explaining Wave Properties

This section is similar to the first in that it is largely a descriptive foundation upon which will be built the study of light in the next two modules. Once again, terms like *reflection*, *refraction*, *diffraction*, and *interference* can be learned best by observing actual waves. The recommended videocassettes are very helpful, particularly if you do not have much equipment.

Students find the study of sound to be a great motivator. This topic is introduced in Section 1 and comes into full bloom in Section 2 with the study of musical instruments.

Section 2: Assignment Answer Key (61 marks)

1. a. Since the ring is free to move, the trough pulse will overshoot and reflect as a trough.

   b. Since the coil is attached to the pole, Newton's third law predicts that the pulse will reflect as a crest.

2. Textbook question 6.a.:

   If the pulse reflects inverted, the medium on the left is less dense than the medium on the right.

   Textbook question 6.b.:

   Since the pulse reflects on the same side, the medium on the left is more dense than the medium on the right.

   Textbook question 6.c.:

   Since the pulse reflects on the same side, the medium on the left is more dense than the medum on the right. This is the same thinking used for textbook question 6. b.

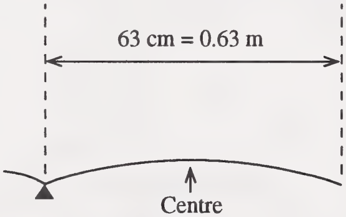
   Textbook question 6.d.:

   Since the pulse reflects on the opposite side of the medium, the medium on the left is less dense than the medium on the right. This is the same thinking used for textbook question 6. a.

   Textbook question 7:

   The bottom should produce the stronger reflection because much less of the initial wave will be transferred to the bottom than to the cool water. In general, more of the energy is reflected if the two media are very different.

3. Textbook question 14.a.:



$v = 265 \text{ m/s}$

$d = 0.63 \text{ m}$ (from centre to end and back)

$t = ?$

$$v = \frac{d}{t}$$

$$\begin{aligned} t &= \frac{d}{v} \\ &= \frac{0.63 \text{ m}}{265 \text{ m/s}} \\ &= 2.377 \times 10^{-3} \text{ s} \\ &= 2.4 \times 10^{-3} \text{ s} \end{aligned}$$

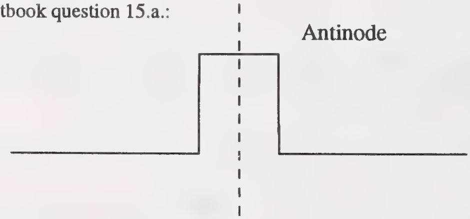
   Textbook question 14.b.:

   The pulse will return to the centre below the resting location because the boundary at the end of the string is rigid.

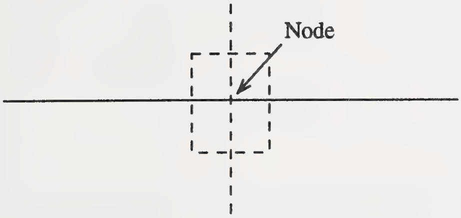
   Textbook question 14.c.:

   The pulses would meet 15 cm from the other end because this location would require both pulses to travel the same total distance.

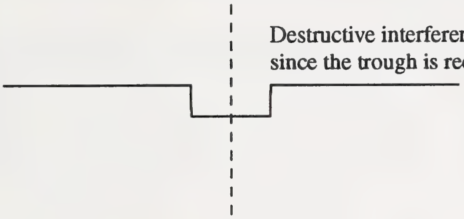
4. Textbook question 15.a.:



Textbook question 15.b.:

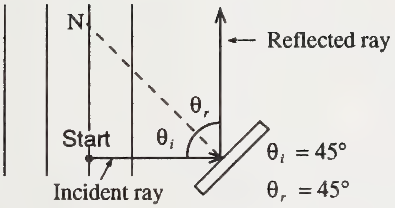


Textbook question 15.c.:



Destructive interference since the trough is reduced

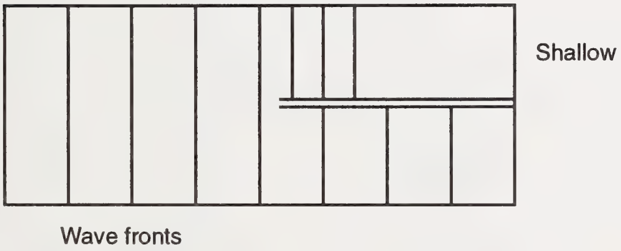
5.



$\theta_i = 45°$

$\theta_r = 45°$

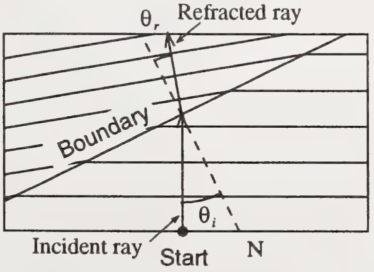
6.



The waves in the shallow region of the diagram should be drawn closer together with a shorter wavelength.

7. The left side of the diagram is deeper. The right side is shallower, as is demonstrated by the waves slowing down, bunching together, and bending.

8. a.



$\theta_i = 26.0°$

$\theta_r = 16.5°$

b. velocity: The velocity decreases as the waves move into the top medium.

frequency: The frequency should stay the same.

wavelength: The wavelength decreases as the waves move into the top medium.

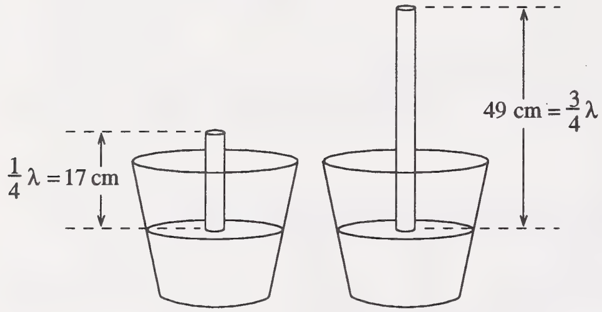
9. Textbook question 1:

Very high frequency sounds require ear parts that can vibrate at these high frequencies. This means that the parts must have low mass and low inertia so that they can respond to the high rate of vibrations.

10. When supersonic aircraft travel at speeds beyond the speed of sound, a shock wave is created. To a listener on the ground, this is heard as a sonic boom. When supersonic aircraft prepare to land and take off, they come close to the ground, making the sonic booms even louder and more annoying.

11. The soldiers are trying to avoid the chance of marching at the resonant frequency of the bridge. If this happened, the bridge would vibrate so strongly that it could break.

12.


$\frac{1}{4}\lambda = 17\text{ cm}$
$49\text{ cm} = \frac{3}{4}\lambda$

Step 1: Find the wavelength of the sound.

$$\left(\frac{3}{4}\lambda\right) - \left(\frac{1}{4}\lambda\right) = \frac{1}{2}\lambda$$

$$(49\text{ cm}) - (17\text{ cm}) = 32\text{ cm}$$

$$\frac{1}{2}\lambda = 32\text{ cm}$$

$$\lambda = 64\text{ cm}$$

$$= 0.64\text{ m}$$

Step 2: Find the frequency of the tuning fork.

$v = 343\text{ m/s}$

$\lambda = 0.64\text{ m}$

$f = ?$

$$v = \lambda f$$

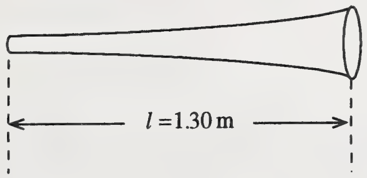
$$f = \frac{v}{\lambda}$$

$$= \frac{343\text{ m/s}}{0.64\text{ m}}$$

$$= 535.9\text{ Hz}$$

$$= 5.4 \times 10^{2}\text{ Hz}$$

13. a.



Step 1: Find the fundamental wavelength.

$$\frac{1}{2}\lambda_1 = l$$
$$\frac{1}{2}\lambda_1 = 1.30\text{ m}$$
$$\lambda_1 = 2.60\text{ m}$$

Step 2: Find the resonant frequency.

$\lambda_1 = 2.60\text{ m}$
$v = 343\text{ m/s}$
$f_1 = ?$

$$v = \lambda_1 f_1$$
$$f_1 = \frac{v}{\lambda_1}$$
$$= \frac{343\text{ m/s}}{2.60\text{ m}}$$
$$= 131.9\text{ Hz}$$
$$= 132\text{ Hz}$$

b.

$$f_2 = 2f_1$$
$$= 2(132\text{ Hz})$$
$$= 264\text{ Hz}$$

$$f_3 = 3f_1$$
$$= 3(132\text{ Hz})$$
$$= 396\text{ Hz}$$

$$f_4 = 4f_1$$
$$= 4(132\text{ Hz})$$
$$= 528\text{ Hz}$$

c. If the temperature dropped, the speed of sound would drop, causing the fundamental frequency and the overtone frequencies to drop. This means that the pitch of the bugle would drop, making the music sound flat.

14. a. Step 1: Calculate the fundamental wavelength.

$f_1 = 147\text{ Hz}$
$v = 343\text{ m/s}$
$\lambda_1 = ?$

$$v = \lambda_1 f_1$$
$$\lambda_1 = \frac{v}{f_1}$$
$$= \frac{343\text{ m/s}}{147\text{ Hz}}$$
$$= 2.\overline{33}\text{ m}$$

Step 2: Calculate the length of the clarinet.

$$\frac{1}{4}\lambda_1 = l$$
$$l = \frac{1}{4}\left(2.\overline{33}\text{ m}\right)$$
$$= 0.58\overline{3}\text{ m}$$

b.

$$f_3 = 3f_1$$
$$= 3(147\text{ Hz})$$
$$= 441\text{ Hz}$$

$$f_5 = 5f_1$$
$$= 5(147\text{ Hz})$$
$$= 735\text{ Hz}$$

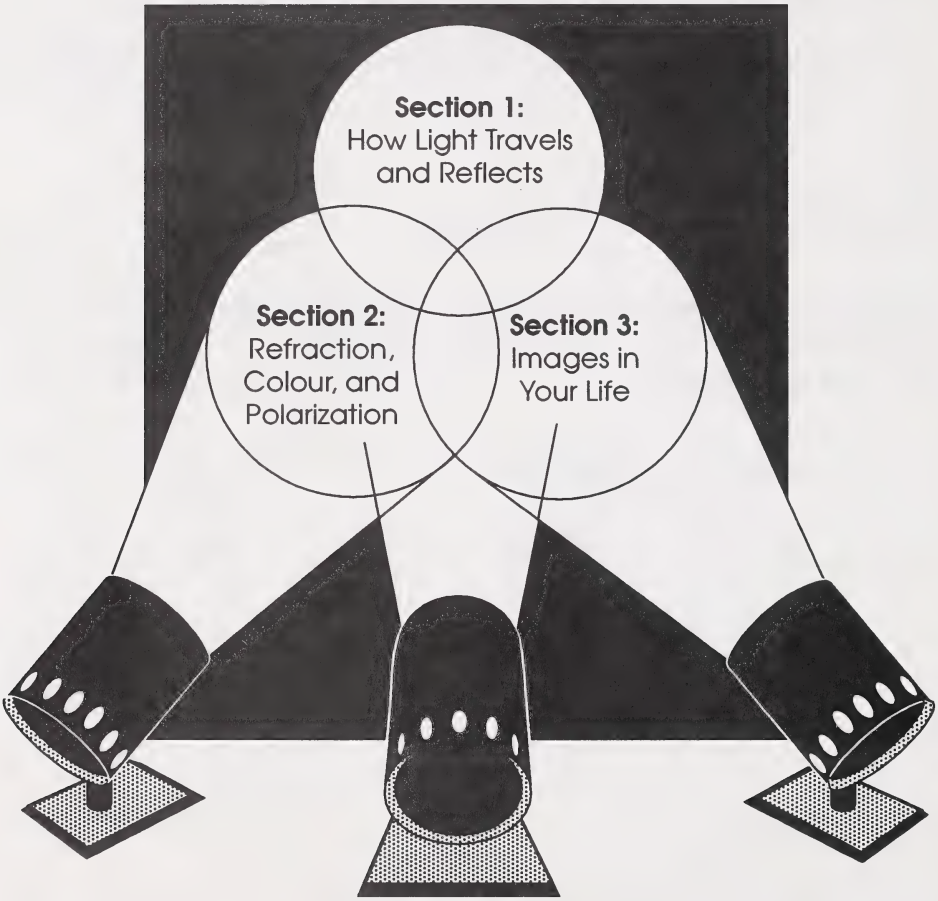
$$f_7 = 7f_1$$
$$= 7(147\text{ Hz})$$
$$= 1029\text{ Hz}$$
$$= 1.03 \times 10^3\text{ Hz}$$

Module 6: Light as a Wave

Overview

The major emphasis of this module is an introduction to light as a form of energy. The module begins by studying the history of light and the conflict that arose between the particle theory and the wave theory of light. Several properties of light are identified and students investigate these properties of light in an attempt to prove or disprove either theory. (Note that this module does not discuss the diffraction or interference of light or the reflection or refraction of light from curved surfaces. These will be analysed in Module 7). After an analysis of the properties of light, students explain the various applications of light properties in science, society, and technology.

Module 6: Light as a Wave


Section 1: How Light Travels and Reflects
Section 2: Refraction, Colour, and Polarization
Section 3: Images in Your Life

Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 6. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 2

Investigation: Pinhole Camera

- large coffee can with a translucent cover
- 5 cm of masking tape
- a 40-W showcase style light bulb in a fixture
- a small finishing nail (size 2)
- a large common nail (size 8)

Section 1: Activity 4

Investigation: Law of Reflection

Students will do **either** Part A **or** Part B of this investigation.

Part A

- a laser (Be sure to follow all safety instructions that accompany the laser.)
- a reflecting surface (mirror)
- a protractor
- masking tape

Part B

- a protractor

Section 2: Activity 1

Investigation: Light Travels from Air into Glass

- semi-circular glass dish (D-dish) that is 8.60 cm in diameter
- soft smooth board measuring about 0.5 m by 0.5 m (A ceiling tile or piece of corrugated cardboard would be ideal.)
- three small stick pins
- ruler
- tape

Investigation: Light Travels from Glass into Air

The materials for this investigation are the same as for the previous investigation.

Section 2: Activity 4

Investigation: Observing the Polarization of Light

- two polarizing filters
- a light source
- a smooth horizontal surface

Section 3: Activity 1

Investigation: Image Formation in Plane Mirrors

- a soft board (corrugated cardboard or ceiling tile – 60 cm × 90 cm)
- one sheet of blank paper
- small plane mirror (4 cm × 8 cm)
- mirror holder (plasticine or play dough)
- three stick pins
- pencil
- tape
- ruler

For this investigation your students will require some base material for supporting the mirror. You may use plasticine, putty, or something similar. If you don't have access to something like that, you may wish to make some play dough. A recipe is provided for you.

- 1 cup of flour
- 1 cup of water
- 1/4 cup of salt
- 1 tablespoon of cooking oil
- 1 tablespoon of cream of tartar

Mix all the ingredients together in a pot and stir constantly over medium heat until the mixture is too thick to stir any longer. Remove the pot from the stove. When the play dough has cooled, remove it from the pot and store it in a sealed plastic container in the refrigerator.

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 6. Please refer to the list presented for Module 1.

Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	35%
Section 2 Assignment	43%
Section 3 Assignment	22%
TOTAL	100%

Section 1: How Light Travels and Reflects

The emphasis in this section is an introduction to the history of the study of light and the two theories of light (the particle theory and wave theory). Propagation and reflection from plane surfaces are investigated in an attempt to prove or disprove either theory.

Section 1: Assignment Answer Key (35 marks)

1. Textbook question 1:

    Light comes through space to Earth.

    Textbook question 10:

    Transparent objects transmit light and permit objects to be seen through them.

    Translucent objects transmit light but do not permit objects to be seen through them.

    Opaque objects do not allow light to pass through. They absorb or reflect light.

2. Textbook question 1:

Since $1\ \text{nm} = 10^{-9}\ \text{m}$, $700\ \text{nm} = 7.00 \times 10^{-7}\ \text{m}$.

Textbook question 3:

$d = 1.5 \times 10^{11}\ \text{m}$

$c = 3.00 \times 10^{8}\ \text{m/s}$

$t = ?$

$$\begin{aligned} t &= \frac{d}{c} \\ &= \frac{1.5 \times 10^{11}\ \text{m}}{3.00 \times 10^{8}\ \text{m/s}} \\ &= 5.0 \times 10^{2}\ \text{s} \end{aligned}$$

Textbook question 4.a.:

$c = 3.00 \times 10^{8}\ \text{m/s}$

$t = 14\ \text{s}$

$d = ?$

$$\begin{aligned} d &= ct \\ &= \left(3.00 \times 10^{8}\ \text{m/s}\right)\left(14\ \text{s}\right) \\ &= 4.2 \times 10^{9}\ \text{m} \end{aligned}$$

Textbook question 4.b.:

$t = 42.5\ \text{h} = 1.53 \times 10^{5}\ \text{s}$

$d = 4.2 \times 10^{9}\ \text{m}$

$v = ?$

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{4.2 \times 10^{9}\ \text{m}}{1.53 \times 10^{5}\ \text{s}} \\ &= 2.8 \times 10^{4}\ \text{m/s} \\ &= 28\ \text{km/s} \end{aligned}$$

Textbook question 4.c.:

$r = 1.5 \times 10^{8}\ \text{km}$

$t = 365.25\ \text{d} = 3.16 \times 10^{7}\ \text{s}$

$v = ?$

$$\begin{aligned} d &= 2\pi r \\ &= 2\pi\left(1.5 \times 10^{8}\ \text{km}\right) \\ &= 9.42 \times 10^{8}\ \text{km} \\ &= 9.4 \times 10^{8}\ \text{km} \end{aligned}$$

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{9.4 \times 10^{8}\ \text{km}}{3.15 \times 10^{7}\ \text{s}} \\ &= 30\ \text{km/s} \\ &= 3.0 \times 10^{4}\ \text{m/s} \end{aligned}$$

Textbook question 6:

$c = 3.00 \times 10^{8}\ \text{m/s}$

$t = 0.1\ \text{s}$

$d = ?$

$$\begin{aligned} d &= ct \\ &= \left(3.00 \times 10^{8}\ \text{m/s}\right)\left(0.1\ \text{s}\right) \\ &= 3 \times 10^{7}\ \text{m} \end{aligned}$$

By comparison, the distance is $\frac{3}{8}$ of the distance around the earth.

Textbook question 7:

$c = 3.00 \times 10^{8}\ \text{m/s}$

$\lambda = 3.0\ \text{cm} = 3.0 \times 10^{-2}\ \text{m}$

$f = ?$

$$\begin{aligned} f &= \frac{c}{\lambda} \\ &= \frac{3.00 \times 10^{8}\ \text{m/s}}{3.0 \times 10^{-2}\ \text{m}} \\ &= 1.0 \times 10^{10}\ \text{Hz} \end{aligned}$$

3. Textbook question 1. a.:

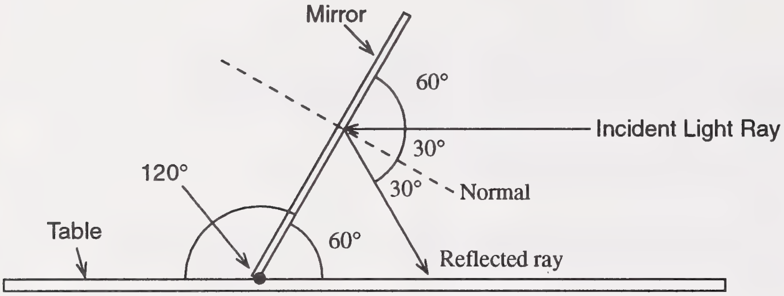
   $\theta_i = \theta_r$. Therefore, $\theta_r = 53°$.

   Textbook question 1. b.:

   The angle between both rays could be calculated as follows:

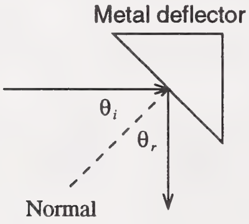
   $2(53°) = 106°$

4.



As shown on the diagram, the angle of reflection is 30°.

5. a. Yes, x-rays reflect the same way that light does. When they strike the metal deflector, they reflect such that $\theta_i = \theta_r$. Also, it can be shown by x-ray photograph that x-rays pass through skin, but reflect off bones, creating an image.



   b. Yes, x-rays propagate the same way that light does.

   - They travel in straight lines as shown by the clear shadows of the bones.
   - They travel at the same speed that light does, as shown in the following calculation.

$$\begin{aligned} c &= f\lambda \\ &= (4.0\times10^{18}\ \text{Hz})(7.5\times10^{-11}\ \text{m}) \\ &= 3.0\times10^{8}\ \text{m/s} \end{aligned}$$

$$\begin{aligned} c &= f\lambda \\ &= (6.0\times10^{17}\ \text{Hz})(5.0\times10^{-10}\ \text{m}) \\ &= 3.0\times10^{8}\ \text{m/s} \end{aligned}$$

Section 2: Refraction, Colour, and Polarization

In this section other properties of light are investigated (refraction, dispersion, colour, and polarization) and the students gain a powerful insight into the wave theory of light being the correct theory to explain the propagation of light. Diffraction, interference, scattering, and diffusion are left to later modules.

Section 2: Assignment Answer Key (43 marks)

1. Textbook question 14.a.:

$\theta_{air} = 45°$
$n_{air} = 1.00$
$n_{glass} = 1.5$
$\theta_{glass} = ?$

$$\sin\theta_{glass} = \frac{n_{air}\left(\sin\theta_{air}\right)}{n_{glass}}$$

$$\sin\theta_{glass} = \frac{(1.00)(\sin 45°)}{(1.5)}$$

$$\theta_{glass} = 28°$$

Textbook question 14.b.:

Angle A = 62°, since 90° – 28° = 62°.
Angle B = 58°, since 180° – (60° + 62°) = 58°.
Angle C = 32°, since 90° – 58° = 32°.

Textbook question 14.c.:

$\theta_{glass} = 32°$
$n_{glass} = 1.5$
$n_{air} = 1.00$
$\theta_{air} = ?$

$$\sin\theta_{air} = \frac{n_{glass}\left(\sin\theta_{glass}\right)}{n_{air}}$$

$$\sin\theta_{air} = \frac{(1.5)(\sin 32°)}{(1.0)}$$

$$\theta_{air} = 53°$$

Textbook question 18:

$v_{plastic} = 1.90 \times 10^8\ \text{m/s}$
$\theta_{air} = 22°$
$v_{air} = 3.00 \times 10^8\ \text{m/s}$
$\theta_{plastic} = ?$

$$\sin\theta_{plastic} = \frac{v_{plastic}\left(\sin\theta_{air}\right)}{v_{air}}$$

$$= \frac{\left(1.90 \times 10^8\ \text{m/s}\right)(\sin 22°)}{\left(3.00 \times 10^8\ \text{m/s}\right)}$$

$$\theta_{plastic} = 14°$$

2. a.

Perceived Colour of Light Reaching the Retina	Nerve Receptor(s) Stimulated at the Retina
Red	R
White	R, G, B
Cyan	G, B
Magenta	R, B
Yellow	R, G
Black	nil

b. The receptor of that colour is damaged.

c. The red receptor has decreased sensitivity, thus only the blue and green receptors are strongly stimulated by the white light, producing cyan.

3. Sunlight refracts in the atmosphere as it travels to your eyes. Your eyes perceive that light travels in a straight line, creating a perception of an image of the sun on the horizon.

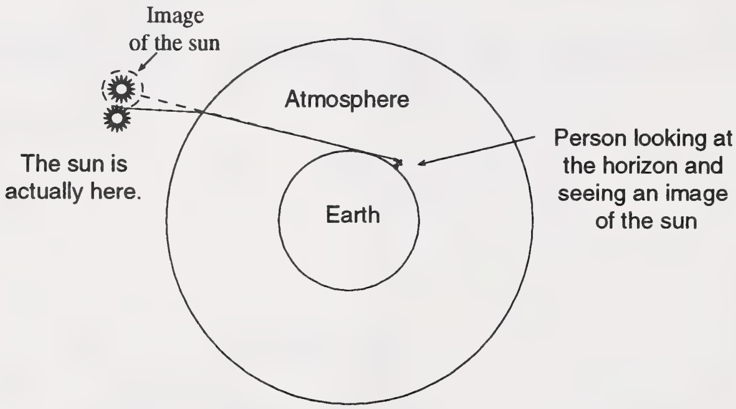
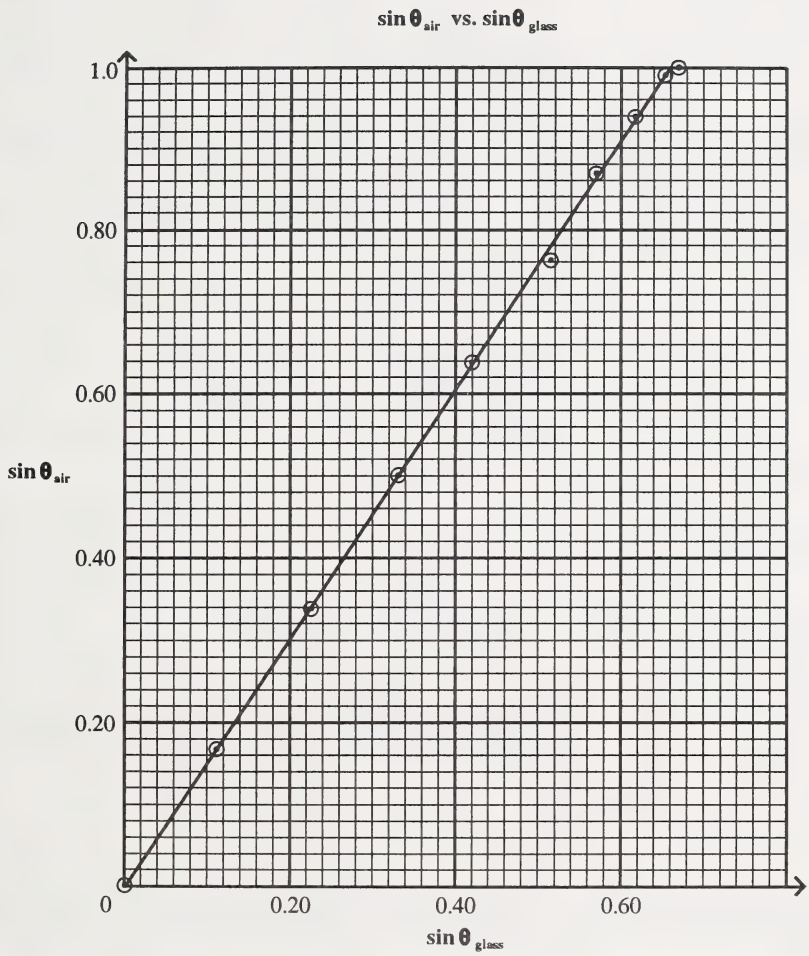


Image of the sun
Atmosphere
Person looking at the horizon and seeing an image of the sun
The sun is actually here.
Earth

4. a.



b. $$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{1.00 - 0.0}{0.660 - 0.0}$$
$$= \frac{1.00}{0.660}$$
$$= 1.52$$

c. The slope represents the index of refraction for glass.

5. You can place a polarizing lens in front of the camera.

6. Take a polarizing lens and look at the light and rotate the lens. If the light darkens and brightens, the light is polarized.

7. a. It will appear yellow since white light contains red and green, which are reflected as yellow. The banana absorbs the blue light.

   b. It will appear yellow since when red and green are reflected together, the combined effect is yellow.

   c. It will appear black since the banana absorbs blue light.

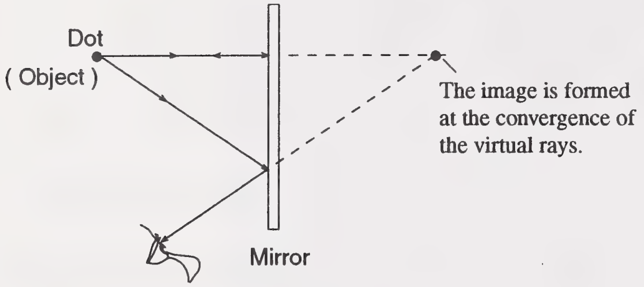
Section 3: Images in Your Life

In this section the properties of reflection and refraction are applied to explain some light phenomena which occur in science, society, and technology.

The formation of an image by a plane mirror is one application that is particularly important because of the bridge between it and the study of curved mirrors and lenses in the next module.

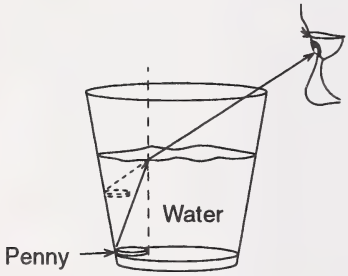
Section 3: Assignment Answer Key (22 marks)

1.



The image is formed at the convergence of the virtual rays.

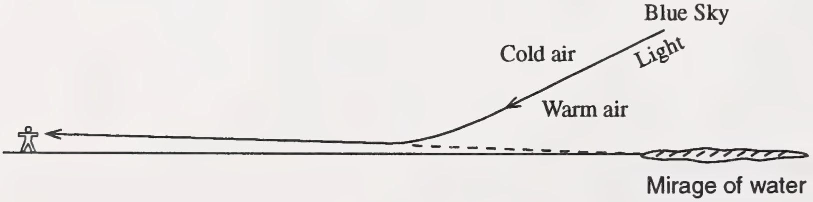
2.



Light is refracted to your eyes. Your eyes perceive that the light travels in a straight line, creating the image shown.

3. Since flint glass has a higher index of refraction, use it as a coating so that it has a lower critical angle, therefore allowing less light to escape.

4.



5. $\theta_{air} = 80.0°$

$n_{air} = 1.00$

$n_{diamond} = 2.42$

$\theta_{diamond} = ?$

$$\sin\theta_{diamond} = \frac{n_{air}(\sin\theta_{air})}{n_{diamond}}$$

$$\sin\theta_r = \frac{(1.00)(\sin 80.0°)}{(2.42)}$$

$$= 24.01°$$

When the ray passes through the diamond to Boundary 2, it will hit at 24.0°. Assume that the angle in the air exists and then find it with Snell's law.

$\theta_{diamond} = 24.0°$

$n_{diamond} = 2.42$

$n_{air} = 1.00$

$\theta_{air} = ?$

$$\sin\theta_{air} = \frac{n_{diamond}(\sin\theta_{diamond})}{n_{air}}$$

$$= \frac{(2.42)(\sin 24.01°)}{(1.00)}$$

$$= 80.0°$$

This question could also be answered by noting that $\theta_{air} = 80.0°$ when $\theta_{diamond} = 24.0°$ regardless of the direction.

6. $n_{air} = 1.00$

$n_{diamond}(\text{red}) = 2.410$

$n_{diamond}(\text{blue}) = 2.450$

$\theta_{air} = 30.0°$

$\theta_r(\text{red}) = ?$

$\theta_b(\text{blue}) = ?$

Red light:

$$\sin\theta_r = \frac{n_{air}(\sin\theta_{air})}{n_{diamond}}$$

$$= \frac{(1.00)(\sin 30.0°)}{(2.410)}$$

$$\theta_r = 12.0°$$

Red light refracts less.

Blue light:

$$\sin\theta_b = \frac{n_{air}(\sin\theta_{air})}{n_{diamond}}$$

$$= \frac{(1.00)(\sin 30.0°)}{(2.450)}$$

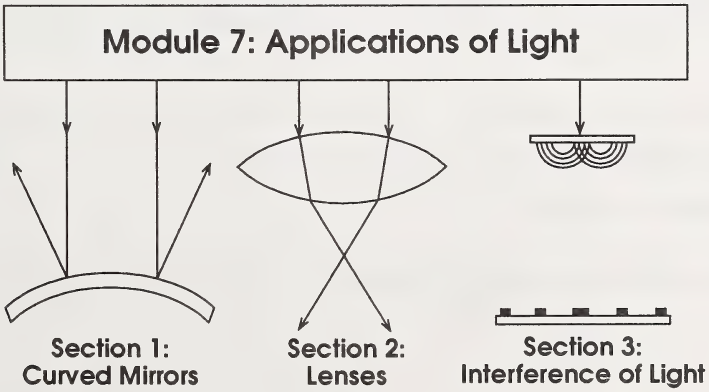
$$\theta_b = 11.8°$$

Module 7: Applications of Light

Overview

This module contains three sections. The first two sections deal with the concepts of reflection and refraction applied to curved mirrors and lenses. In both of these sections the students will perform investigations which look at the images produced by mirrors and lenses. Then the students will learn how to locate these images by using ray diagrams and by applying the mirror or lens equation.

In the third section students will work with the concepts of diffraction and interference. They will discover how these concepts were used to prove that light is a wave. As well, the students will investigate the pattern produced by light travelling through two slits or a diffraction grating.


Module 7: Applications of Light
Section 1: Curved Mirrors
Section 2: Lenses
Section 3: Interference of Light

Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 7. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 1

Investigation: The Common Spoon Reflector

- a large, shiny soup spoon

Section 1: Activity 2

Investigation: Images Formed by Curved Mirrors

- convex mirror
- concave mirror
- metre stick or measuring tape
- candle
- base material to support mirrors (play dough or putty)
- a cardboard box 4 or 5 cm high (a tissue box is ideal)
- a small piece of cardboard 10 cm × 10 cm
- screen (piece of white paper or white cardboard)
- a room with a window that can be made very dark
- a table
- masking tape

Section 2: Activity 2

Investigation: Images Formed by Lenses

- convex lens
- concave lens
- metre stick or measuring tape
- candle
- base material to support lenses (play dough or putty)
- a cardboard box 4 or 5 cm high (a tissue box is ideal)
- a small piece of cardboard 10 cm × 10 cm
- screen (piece of white paper or cardboard)
- a room with a window that can be made very dark
- a table
- masking tape

Section 3: Activity 2

Investigation: Two-Source Interference

- a window with daylight coming through
- masking tape
- a ruler
- the two tear-out pages at the end of the Appendix of this module

Section 3: Activity 3

Investigation: Determining the Wavelength of Light

- metre stick or metric measuring tape
- index card
- 40-W straight filament lamp (showcase style bulb)
- play dough or putty
- tape
- diffraction grating

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 7. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Wave Particle Duality: The Wave Model*, TV Ontario (Available through ACCESS Network)
– *Convex and Concave Lenses*, Films for the Humanities and Sciences

Both of these programs provide a concise reinforcement of the main ideas.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	34%
Section 2 Assignment	33%
Section 3 Assignment	33%
TOTAL	100%

Section 1: Curved Mirrors

Curved mirrors have several applications. Rearview mirros, satellite dishes, and flashlights are excellent examples of how the reflection of light from curved surfaces can be used. The students will investigate the images formed by curved mirrors and then apply ray diagrams and the mirror equation to accurately locate the images.

The mirror equation is a difficult one to rearrange. For example, when $\frac{1}{f}=\frac{1}{d_i}+\frac{1}{d_o}$ is rearranged for d_i, it becomes $d_i=\frac{f\,d_o}{d_o-f}$, but students may find it easier to use $d_i=\left(\frac{1}{f}-\frac{1}{d_o}\right)^{-1}$, especially if they know how to use the reciprocal function on their scientific calculator $\left(\frac{1}{x}\text{ or } x^{-1}\right)$.

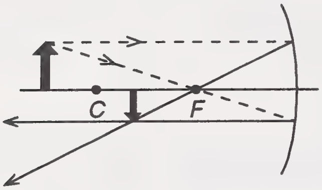
Another area that students find challenging is locating images. The student will not see the image when the object is at or very near the focal point. At all other positions, the student should be patient and look for the clearest image.

Section 1: Assignment Answer Key (34 marks)

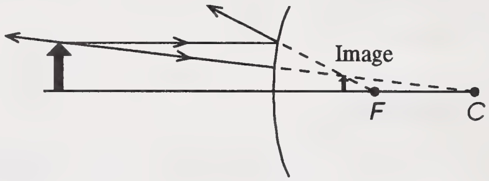
1. a. The mirror must be concave since the image is both upright and larger. A convex mirror produces an upright image, but it is always smaller than the actual object.

   b. The image would get larger first, but would soon disappear when the object gets to the focal point. After that, the image would be inverted and would get smaller as the distance from the mirror increased.

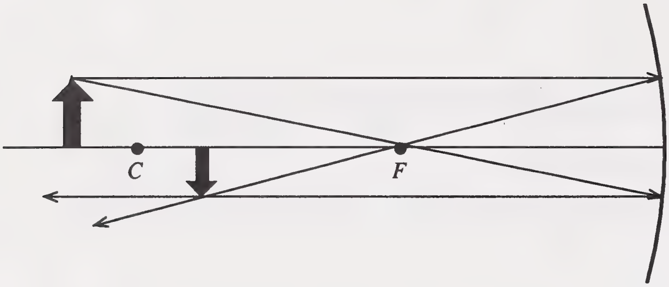
2. a.



b.



3. a.



   b. The image distance should be close to 7.2 cm if the ray diagram is done correctly.

   c. $$\frac{1}{f}=\frac{1}{d_i}+\frac{1}{d_o}$$

$$d_i=\frac{f\,d_o}{d_o-f}$$

$$d_i=\frac{(4.0\text{ cm})(9.0\text{ cm})}{9.0\text{ cm}-4.0\text{ cm}}$$

$$d_i=7.2\text{ cm}$$

The students should compare this answer to their measurements in 3. b.

   d. The height should be close to 8.0 mm if the ray diagram is done correctly.

$$\frac{h_i}{h_o}=\frac{-d_i}{d_o}$$

$$h_i=\frac{-d_i h_o}{d_o}$$

$$h_i=\frac{-(7.2\text{ cm})(1.0\text{ cm})}{9.0\text{ cm}}$$

$$h_i=-0.80\text{ cm}$$

The students should compare this height to their measurements.

4. a. $f = -36.0 \text{ cm}$

$d_o = 2.4 \text{ m} = 2.4 \times 10^2 \text{ cm}$

$d_i = ?$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$d_i = \frac{f\,d_o}{d_o - f}$$

$$d_i = \frac{(-36.0 \text{ cm})(2.4 \times 10^2 \text{ cm})}{2.4 \times 10^2 \text{ cm} - (-36.0 \text{ cm})}$$

$$d_i = -31 \text{ cm}$$

The virtual image appears 31 cm behind the mirror.

b. The mirror is convex since the focal length is negative.

c. The image is actually closer to the mirror, but it appears to be further because it is smaller than the actual shopper.

5. a. $d_o = 92.5 \text{ mm}$ $\quad d_i = 46.5 \text{ mm}$

b. $$m = \frac{-d_i}{d_o} = \frac{-46.5 \text{ mm}}{92.5 \text{ mm}} = -0.503$$

c. $h_o = 13.5 \text{ mm}$ $\quad h_i = -6.8 \text{ mm}$

$$m = \frac{-h_i}{h_o} = \frac{-6.8 \text{ mm}}{13.5 \text{ mm}} = -0.504$$

6. a. $d_i = -19.5 \text{ mm}$ $\quad d_o = 39.5 \text{ mm}$

b. $$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$= \frac{1}{(39.5 \text{ mm})} + \frac{1}{(-19.5 \text{ mm})}$$

$$= \left(0.025\,32 \text{ mm}^{-1}\right) + \left(-0.051\,28 \text{ mm}^{-1}\right)$$

$$\frac{1}{f} = -0.025\,962$$

$$f = -38.5 \text{ mm}$$

c. $f = -35.0 \text{ mm}$

The differences could be due to errors in measurements. Errors could also be due to incorrectly measuring d_o and d_i from the wrong side of the mirror. Finally, it is unlikely that the textbook was intended to be used this way, so it is also inaccurate.

Section 2: Lenses

Lenses have several important applications in microscopes, telescopes, and eyeglasses. Refraction is the principle behind the images formed and students will refer back to Module 6 for review of this concept. In this section the student will investigate the images formed by lenses. Then the student will apply ray diagrams and the lens equation to locate the images formed by specific lenses.

The differences between lenses and mirrors should be emphasized as much as similarities. Refraction and reflection are not the same concepts and affect light in very different ways.

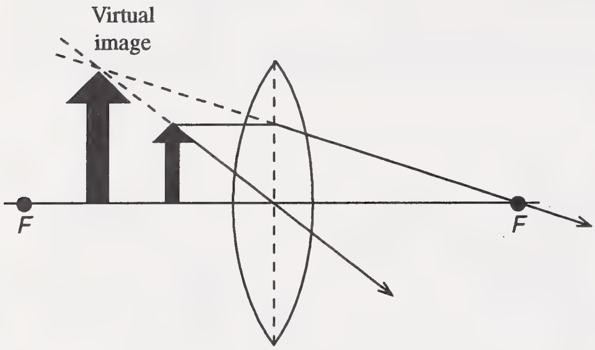
Section 2: Assignment Answer Key (33 marks)

1. a. Point the lens at a distant object through a window. Locate the image of this object on the other side of the lens. The focal length is the distance to the sharply defined image.

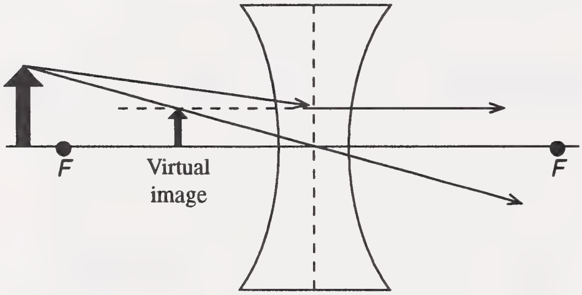
   b. Either of these answers are correct.

   - Test to see if a real image of a distant object can be formed. If so, it is convex; if not, it is concave.
   - Measure the thickness of the centre of the lens and the thickness of the outer portion. If the lens is thinner in the middle, it is concave. If it is thicker in the middle, it is convex.

2. a.



   b.



3. $f = 3.50\text{ cm}$
   $d_i = 4.08\text{ cm}$
   $d_o = ?$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$d_o = \frac{f\,d_i}{d_i - f}$$

$$d_o = \frac{(3.50\text{ cm})(4.08\text{ cm})}{(4.08 - 3.50)\text{ cm}}$$

$$d_o = 25\text{ cm}$$

4. a. The real image will also be located 40.0 cm from the lens since the magnification must be 1.00.

b. Use either Method A or Method B.

Method A

The d_o must be at 2F.
Therefore, $2f = 40.0$ cm and $f = 20.0$ cm.

Method B

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$f = \frac{d_i d_o}{d_o + d_i}$$

$$f = \frac{(40.0\text{ cm})(40.0\text{ cm})}{(40.0 + 40.0)\text{ cm}}$$

$$f = 20.0\text{ cm}$$

5. $f = 12.7$ cm
$d_o = 4.2$ cm
$m = ?$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$d_i = \frac{f d_o}{d_o - f}$$

$$d_i = \frac{(12.7\text{ cm})(4.2\text{ cm})}{(4.2 - 12.7)\text{ cm}}$$

$$d_i = -6.3\text{ cm}$$

$$m = \frac{-d_i}{d_o}$$

$$m = \frac{-(-6.3\text{ cm})}{4.2\text{ cm}}$$

$$m = 1.5$$

The magnification is 1.5.

6. a. $d_i = 25.2$ mm

$d_o = 51.3$ mm

b.
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$= \frac{1}{(51.3\text{ mm})} + \frac{1}{(25.2\text{ mm})}$$

$$= 0.019\ 49\text{ mm}^{-1} + 0.039\ 68\text{ mm}^{-1}$$

$$\frac{1}{f} = 0.059\ 17\text{ mm}^{-1}$$

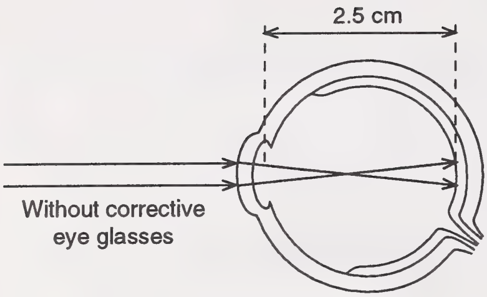
$$f = 16.9\text{ mm}$$

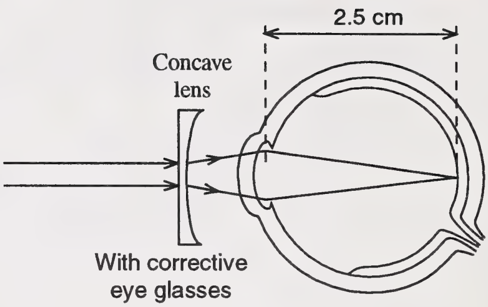
c. The focal length is 16.5 mm on one side and 17 mm on the other. The differences are likely due to slight printing errors in the textbook. Another source of error could be poor measurements of d_i and d_o.

7. a. The focal length is the distance from the lens to the focal point, which is 2.5 cm.

b. This person suffers from myopia because the focal length is too short. Even when looking at far away objects, the focal length does not reach the retina as it does with normal vision. Normal vision is shown in the diagram at the beginning of the question.

c.





d. $d_i = 2.5\text{ cm}$

$= 0.025\text{ m}$

$f = 2.1\text{ cm}$

$= 0.021\text{ cm}$

$d_o = ?$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$

$$= \frac{1}{0.021\text{ m}} - \frac{1}{0.025\text{ m}}$$

$$= \left(47.62\text{ m}^{-1}\right) - \left(40\text{ m}^{-1}\right)$$

$$\frac{1}{d_o} = 7.62\text{ m}^{-1}$$

$$d_o = 0.13\text{ m}$$

$d_i = 2.5\text{ cm}$

$= 0.025\text{ m}$

$f = 2.3\text{ cm}$

$= 0.023\text{ m}$

$d_o = ?$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$

$$= \frac{1}{0.023\text{ m}} - \frac{1}{0.025\text{ m}}$$

$$= \left(43.48\text{ m}^{-1}\right) - \left(40\text{ m}^{-1}\right)$$

$$\frac{1}{d_o} = 3.48\text{ m}^{-1}$$

$$d_o = 0.29\text{ m}$$

This person would only be able to clearly see objects that were 0.13 m to 0.29 m in front of their eyes.

Section 3: Interference of Light

In Section 3 the students will review the concepts of interference and diffraction, which they studied previously in Module 5. The students must then apply these concepts to two-slit interference patterns. Through a variety of investigations, the students will come to understand the geometric principles behind the famous experiment performed by Thomas Young. These principles led to the calculation of the wavelength for monochromatic light.

If lasers are available, students are urged to use them. However, exercise caution, since permanent eye damage can result from careless handling. Lasers provide the best visible interference patterns when used with two-slit films or diffraction gratings.

Section 3: Assignment Answer Key (33 marks)

1. $d = 9.66 \times 10^{-6}\text{ m}$

$l = 1.64\text{ m}$

$x = 8.95\text{ cm}$

$= 0.0895\text{ m}$

$\lambda = ?$

$$\lambda = \frac{xd}{nl}$$

$$\lambda = \frac{\left(8.95\text{ cm}\right)\left(9.66 \times 10^{-6}\text{ m}\right)}{\left(1\right)\left(1.64\text{ m}\right)}$$

$$\lambda = 5.27 \times 10^{-5}\text{ cm}$$

The wavelength was $5.27 \times 10^{-5}\text{ cm}$.

2. $\lambda = 585\text{ nm}$

$= 5.85 \times 10^{-7}\text{ m}$

$l = 80.0\text{ cm}$

$x = 6.7\text{ cm}$

$n = 3$

$d = ?$

$$\lambda = \frac{x\,d}{n\,l}$$

$$d = \frac{n\,l\,\lambda}{x}$$

$$d = \frac{(3)(80.0\text{ cm})(5.85 \times 10^{-7}\text{ m})}{(6.7\text{ cm})}$$

$$d = 2.1 \times 10^{-5}\text{ m}$$

The slits are 2.1×10^{-5} cm apart.

3. $l_1 = 1.35\text{ m}$

$x_1 = 18.8\text{ cm}$

$l_2 = 1.00\text{ m}$

$x_2 = ?$

$n = 1$

Step 1:

$$\lambda = \frac{d(\sin\theta)}{n}$$

$$\sin\theta = \frac{n\,\lambda}{d}$$

$$\theta = \left(\sin^{-1}\right)\frac{n\,\lambda}{d}$$

As shown, the diffraction angle only depends on the variables n, λ, and d. Since these things are constant, it is the same angle in both cases.

Step 2: $\tan\theta = \dfrac{x_1}{l_1}$ $\qquad$ $\tan\theta = \dfrac{x_2}{l_2}$

by substitution

$$\frac{x_1}{l_1} = \frac{x_2}{l_2}$$

$$x_2 = \frac{x_1 l_2}{l_1}$$

$$= \frac{(18.8\text{ cm})(1.00\text{ m})}{1.35\text{ m}}$$

$$= 13.9\text{ cm}$$

4. a. $x = 29\text{ mm} = 29\text{ cm}$
$l = 93.2\text{ mm} = 93.2\text{ cm}$

b. $x = 29\text{ cm}$

$l = 93.2\text{ cm}$

$d = \dfrac{1.0\text{ cm}}{4800\text{ lines}} = 2.083 \times 10^{-4}\text{ cm}$

$n = 1$

$\lambda = ?$

$$\lambda = \frac{x\,d}{n\,l}$$

$$\lambda = \frac{(29\text{ cm})(2.083 \times 10^{-4}\text{ cm})}{(1)(93.2\text{ m})}$$

$$\lambda = 6.48 \times 10^{-5}\text{ cm}$$

c. $\theta = 17.5^\circ$

$d = 2.083 \times 10^{-4}\text{ cm}$

$n = 1$

$\lambda = ?$

$$\lambda = \frac{d\sin\theta}{n}$$

$$\lambda = \frac{(2.083 \times 10^{-4}\text{ cm})(\sin 17.5^\circ)}{1}$$

$$\lambda = 6.26 \times 10^{-5}\text{ cm}$$

d. The equation $\lambda = \dfrac{x\,d}{n\,l}$ uses some approximations that allow it to work nicely for small angles of diffraction. However, when $\theta > 6^\circ$, this equation provides answers with only two digits of precision. Further, when $\theta > 12^\circ$, this equation can provide only one digit of precision. Since the value of θ is 17.5°, the other equation is more precise for determining the wavelength.

5. Textbook question 12:

number of lines = 12 000
distance containing the lines = 1 cm = 0.01 m
distance between consecutive lines = d = ?

$$\begin{aligned} d &= \frac{\text{distance containing the lines}}{\text{number of lines}} \\ &= \frac{0.01\ \text{m}}{12\ 000} \\ &= 8.333 \times 10^{-7}\ \text{m} \end{aligned}$$

$d = 8.333 \times 10^{-7}$ m

$\lambda_{red} = 632$ nm $= 6.32 \times 10^{-7}$ m

$\lambda_{blue} = 421$ nm $= 4.21 \times 10^{-7}$ m

$n = 1$

$\theta = ?$

Red light

$$\begin{aligned} \sin\theta &= \frac{1\left(6.32 \times 10^{-7}\ \text{m}\right)}{8.333 \times 10^{-7}\ \text{m}} \\ &= 0.7584 \\ \theta &= 49.3° \end{aligned}$$

Blue light

$$\begin{aligned} \sin\theta &= \frac{1\left(4.21 \times 10^{-7}\ \text{m}\right)}{8.333 \times 10^{-7}\ \text{m}} \\ &= 0.5052 \\ \theta &= 30.3° \end{aligned}$$

6. $d = 4.0$ m

$f = 325$ Hz

$v = 343$ m/s

$\lambda = ?$

$l = 4.5$ m

$x = ?$

Step 1:
$$\begin{aligned} v &= \lambda f \\ \lambda &= \frac{v}{f} \\ &= \frac{343\ \text{m/s}}{325\ \text{Hz}} \\ &= 1.055\ \text{m} \end{aligned}$$

Step 2: Since the spacing from node to node is equal to the spacing from antinode to antinode, the two-source equation can be used to solve for x.

Step 3:
$$\begin{aligned} \lambda &= \frac{xd}{nl} \\ x &= \frac{nl\lambda}{d} \\ x &= \frac{(1)(4.5\ \text{m})(1.055\ \text{m})}{4.0\ \text{m}} \\ x &= 1.2\ \text{m} \end{aligned}$$

Points of destructive interference would be 1.2 m apart.

7. a. $x_1 = \dfrac{76.8\ \text{mm}}{6} = 12.8\ \text{mm}$

$x_2 = \dfrac{96.0\ \text{mm}}{5} = 19.2\ \text{mm}$

b. $x_1 = 12.8$ mm

$x_2 = 19.2$ mm

$d_1 = \dfrac{1\ \text{cm}}{5000\ \text{lines}} = 2.00 \times 10^{-4}\ \text{cm}$

$d_2 = ?$

Step 1:

$$\lambda = \frac{xd}{nl}$$

$$\begin{tikzcd} & n\lambda l = xd \arrow[dl] \arrow[dr] & \\ n\lambda l = x_1 d_1 & & n\lambda l = x_2 d_2 \end{tikzcd}$$

By substitution, $x_1 d_1 = x_2 d_2$.

Step 2: $x_1 d_1 = x_2 d_2$

$$d_2 = \frac{x_1 d_1}{x_2}$$

$$= \frac{(12.8\ \text{mm})(2.00 \times 10^{-4}\ \text{cm})}{19.2\ \text{mm}}$$

$$= 1.333 \times 10^{-4}\ \text{cm}$$

Step 3: $\dfrac{1\ \text{line}}{1.333 \times 10^{-4}\ \text{cm}} = \dfrac{x\ \text{lines}}{1.00\ \text{cm}}$

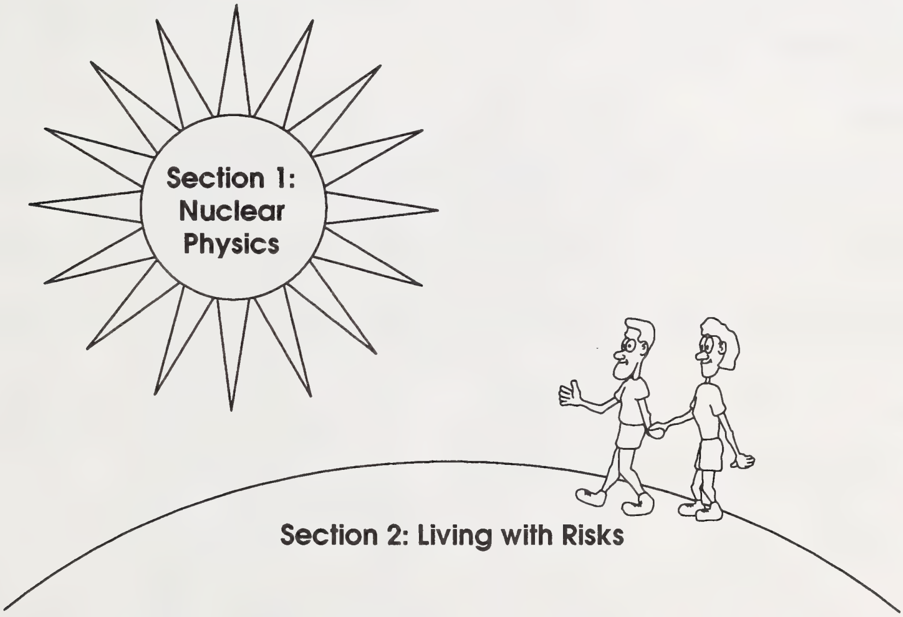
$$x = \frac{(1\ \text{line})(1.00\ \text{cm})}{1.333 \times 10^{-4}\ \text{cm}}$$

$$= 7.50 \times 10^{3}\ \text{lines}$$

Module 8: Physics for Life: Assessing Risks and Benefits

Overview

This module introduces students to the basic ideas of nuclear physics and provides students with some insights about why nuclear applications can be so controversial. The whole module is presented in a survey fashion to acquaint students with only the main ideas. This is why the video component is such a good teaching resource here, since the curriculum does not imply a great depth of coverage. Students should be presented with a learning environment that allows them to develop their own viewpoint about the risks involved with nuclear technologies. The stress should not be so much on their particular opinions, but rather on how well they can justify their particular points of view.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 8. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 2

Students will do **one** of these investigations.

Investigation: A Group of Students Simulate Half-life

- 20 pennies
- graph paper

Investigation: One Student Simulates Half-life

- 100 pennies
- a shoe box
- graph paper

Additional Resources

- The same resources listed for Module 1 can provide additional support and information for teaching Module 8. Please refer to the list presented for Module 1.

- The topics of risk and risk assessment are new to most science teachers. Excellent background reading for teachers can be found in the April 17, 1987 edition of *Science*. This journal provides six articles on the issues of risk assessment. It is worth noting that the articles *Risk Assessment and Comparisons: An Introduction*, by R. Wilson and E.A.C. Crouch, and *Perception of Risk*, by Slovic, were used extensively in guiding the design of Section 2 of this module.

Possible Media

Videocassettes – *Nuclear Physics*, TV Ontario (Available through ACCESS Network). This is essential to Section 1 as there is no pathway.
– *Nova: Back to Chernobyl*, Vestron Video (Available through ACCESS Network)

These videocassettes are crucial for the instruction of this module. They motivate, enlighten, explain, and enliven the students to this whole topic in a very concise way.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	60%
Section 2 Assignment	40%
TOTAL	100%

Section 1: Nuclear Physics

This section introduces students to the main ideas behind nuclear power. It would be a mistake to make this study either overly detailed or too quantitative since the intention is simply to acquaint students with this topic.

Section 1: Assignment Answer Key (60 marks)

1. $^{64}_{29}\text{Cu}$

2. $^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\text{He}$

3. $^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e}$

   Note that the decay of carbon 14 also includes the emission of an antineutrino, but this has been omitted from the solution shown in the interest of simplicity.

4. $^{34}_{15}\text{P} \rightarrow {}^{34}_{16}\text{S} + {}^{0}_{-1}\text{e} + \gamma$

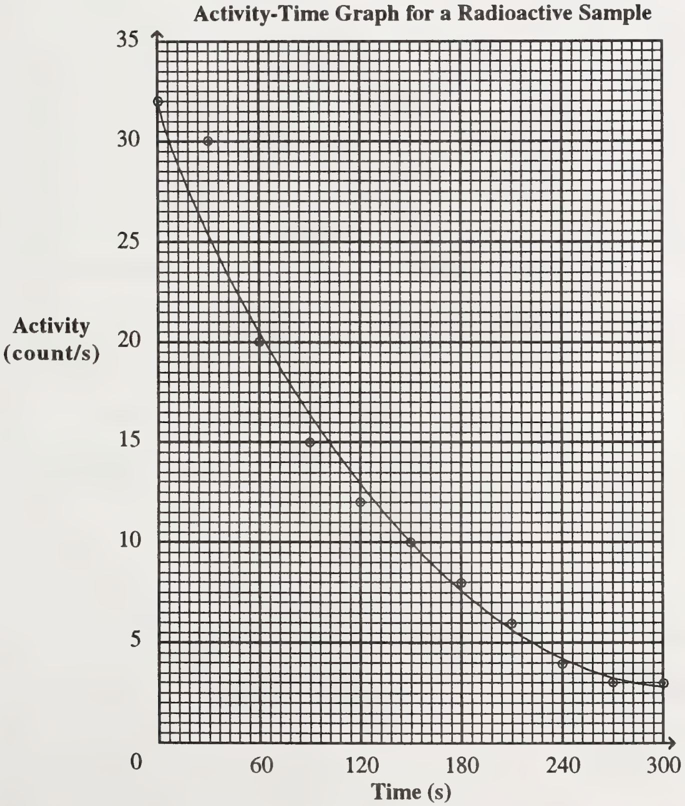
5. $^{65}_{29}\text{Cu} + {}^{1}_{0}\text{n} \rightarrow {}^{65}_{28}\text{Ni} + {}^{1}_{1}\text{p}$

   The new isotope is nickel 65 $\left(^{65}_{28}\text{Ni} \right)$.

6. $^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{96}_{40}\text{Zr} + 3\left(^{1}_{0}\text{n} \right) + {}^{136}_{52}\text{Te}$

   The new isotope is tellurium 136 $\left(^{136}_{52}\text{Te} \right)$.

7. a.



b. The following information was obtained from the graph.

$$\left.\begin{array}{l}\text{from 32 counts/s to 16 counts/s in 93 s}\\ \text{from 20 counts/s to 10 counts/s in 87 s}\\ \text{from 10 counts/s to 5 counts/s in 72 s}\\ \text{from 16 counts/s to 8 counts/s in 81 s}\\ \text{from 12 counts/s to 6 counts/s in 81 s}\end{array}\right\}\text{The average of these half-lives is 82.8 s = 83 s}$$

The activity is one-half of its original amount after its half-life period. From the data, you could conclude that the half-life is approximately 83 s. Note that answers ranging from 78 s to 93 s could be considered valid because this is an estimation based on the curve drawn for the graph.

8. Textbook question 13:

In six years, three half-lives would have occurred. Therefore, the original sample would have been cut in half three times.

$$\begin{aligned}\text{fraction remaining} &= \text{original sample} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}\\ &= \text{original sample} \times \frac{1}{8}\end{aligned}$$

Only 1/8 of the original sample would remain. Note that the equation can also be used to solve this problem.

$N_o = 100\%$

$n = 6 \div 2 = 3$

$N = ?$

$$\begin{aligned}N &= N_o\left(\frac{1}{2}\right)^n\\ &= 100\%\left(\frac{1}{2}\right)^3\\ &= 12.5\%\end{aligned}$$

9. a. Step 1: Find the mass of all the nuclear components.

$$\begin{array}{r}\text{mass of 6 protons} = 6\left(1.673\,53 \times 10^{-27}\text{ kg}\right) = 1.004\,11 \times 10^{-26}\text{ kg}\\ +\text{mass of 6 neutrons} = 6\left(1.674\,92 \times 10^{-27}\text{ kg}\right) = 1.004\,95 \times 10^{-26}\text{ kg}\\ \hline \text{total mass of nuclear components} = 2.009\,06 \times 10^{-26}\text{ kg}\end{array}$$

Step 2: The mass defect is the mass of the components minus the mass of the nucleus.

$$\begin{array}{r}2.009\,06 \times 10^{-26}\text{ kg}\\ -1.992\,64 \times 10^{-26}\text{ kg}\\ \hline 1.642 \times 10^{-28}\text{ kg}\end{array}$$

b. $$\begin{aligned}E &= mc^2\\ &= \left(1.642 \times 10^{-28}\text{ kg}\right)\left(3.00 \times 10^8\text{ m/s}\right)^2\\ &= 1.48 \times 10^{-11}\text{ J}\end{aligned}$$

10. Step 1: Find the total mass of the reactants.

$$\begin{array}{r}\text{mass of U 235} = 390.229\,81 \times 10^{-27}\text{ kg}\\ +\text{mass of 1 neutron} = 1.674\,92 \times 10^{-27}\text{ kg}\\ \hline 391.904\,73 \times 10^{-27}\text{ kg}\end{array}$$

Step 2: Find the total mass of the products.

$$\begin{array}{r}\text{mass of Sr 90 nucleus} = 149.295\,41 \times 10^{-27}\text{ kg}\\ \text{mass of Xe 136} = 225.679\,38 \times 10^{-27}\text{ kg}\\ \text{mass of 10 neutrons} = 16.749\,20 \times 10^{-27}\text{ kg}\\ \hline 391.723\,99 \times 10^{-27}\text{ kg}\end{array}$$

Step 3: Calculate the mass that was converted to energy.

$$\begin{array}{r} 391.904\ 73 \times 10^{-27}\ \text{kg} \\ -391.723\ 99 \times 10^{-27}\ \text{kg} \\ \hline \text{change in mass} = 0.180\ 74 \times 10^{-27}\ \text{kg} \\ = 1.8074 \times 10^{-28}\ \text{kg} \end{array}$$

Step 4: Calculate the energy released.

$$\begin{aligned} E &= mc^2 \\ &= \left(1.8074 \times 10^{-28}\ \text{kg}\right)\left(3.00 \times 10^{8}\ \text{m/s}\right)^2 \\ &= 1.63 \times 10^{-11}\ \text{J} \end{aligned}$$

Section 2: Living with Risks

This section introduces the ideas of risk assessment and risk perception. The main theme that runs through this section is that since the process of producing a risk assessment is so very different from the process of forming a risk perception, the outcomes of these approaches are often quite divergent. Students are encouraged to see the value in both approaches and to understand the importance of dialogue between those that hold conflicting views.

Section 2: Assignment Answer Key (40 marks)

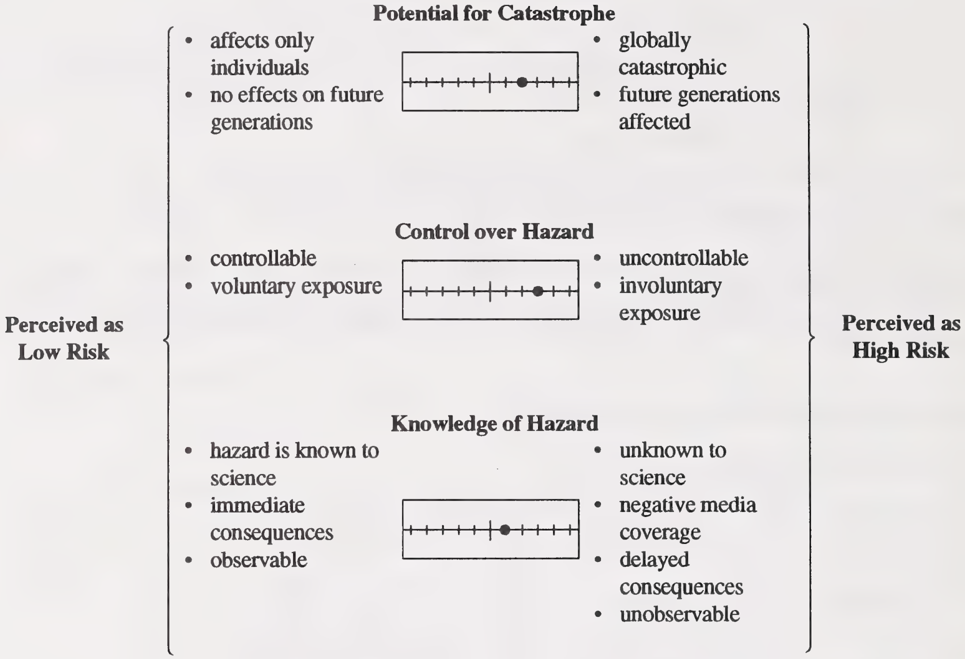
1. The following chart best answers this question.

	Risk Assessment	Risk Perception
Who does this?	experts	members of the general public
How is this done?	statistical analysis	thinking about factors that influence the perception of risk
What is produced?	a statistical assessment of risk	a judgement in the mind of the person

2. Students should choose **two** of the following:

   - This statistic is beyond the limit of understanding for most people, since anything smaller than 1 in 10 000 becomes meaningless.
   - If their opinion is based on a risk perception, there may be a significant sense of dread due to the potential for catastrophe, the lack of control over the hazard, and the lack of knowledge of the hazard. This perception of dread is unlikely to change due to one statistic.
   - Deeply held opinions are very difficult to change.
   - The level of suspicion and mistrust of the experts by some members of society may detract from their willingness to accept this statistic as being valid.

3. a. The following answers provide one example of many possibilities.



b. Flying as a passenger in a commercial airliner has a great potential for catastrophe since hundreds of people can be killed in a very short time. These types of accidents also give the passenger little chance of controlling the outcome, since the accidents usually involve the whole aircraft falling to the ground. Although the hazard is known and is observable, negative media coverage of crash sites has left a deep, negative impression on many people.

4. The following answers show likely answers for each topic. These are not the only answers for each topic. Although student responses should be graded according to the criteria described in the instructions given, and not solely upon the particular opinion stated, the best answers will likely disagree with each topic since these positions are easier to support.

Topic A

In this essay I will explain why I disagree with the statement given under Topic A. A Chernobyl-type accident could never happen in a CANDU 3 reactor due to the design differences between this reactor and the Soviet RBMK reactor.

This first major difference in design concerns the use of graphite blocks as the moderator in the Soviet reactor. The graphite blocks allow the process of fission to continue even if safe operating temperatures have been exceeded and the water has boiled away. In fact, if the water does boil away, the reactor core heats up even more. In contrast, CANDU 3 reactors use heavy water as the moderator. This means that if safe operating temperatures are exceeded and the water boils away, the process of fission will slow down by itself since it can't continue without a moderator.

The second major difference in design is the lack of a containment building at the Chernobyl nuclear plant. Had a containment building been in place, the large cloud of radioactive materials would not have been released into the environment. CANDU 3 reactors incorporate a containment building as part of their basic design.

The accident at Chernobyl was primarily due to a combination of operator error and poor design. Although the potential for human error can never be entirely eliminated from any system, the superior design of the CANDU 3 reactors make accidents on the scale of Chernobyl a virtual impossibility.

Topic B

In this essay I will explain why I disagree with the statement given under Topic B. **Both** coal-fired and nuclear generating stations have environmental problems, making it unclear whether one is clearly the better environmental choice than the other.

The environmental problems associated with using coal to generate electricity stem largely from the emissions released when coal is burned. Carbon dioxide is a greenhouse gas that is thought to contribute to global warming. Although the extent of the problems related to global warming is still being debated, many scientists would argue that the environmental consequences will be severe. Other emissions include sulfur dioxide and nitrous oxide, which both cause acid rain. Acid rain causes chemical changes in soils and bodies of water. It alters ecosystems permanently by reducing soil fertility. Many other compounds, such as small particles of carbon (soot) and heavy metals, are also released into the atmosphere when coal is burned. Smog, asthma, and some forms of cancer have been linked to these emissions. Clearly the burning of coal does create problems for the environment.

Nuclear power plants also have the potential for a negative impact on the environment. In this case, it is the disposal of nuclear waste that causes the greatest concern. The spent fuel is actually more radioactive than the original fuel because it contains so many different radioactive isotopes, all in various stages of radioactive decay, continually emitting all three types of nuclear radiation. Although it was originally thought that the spent fuel could be reprocessed, such a method has not yet been devised. In Canada the spent fuel must be stored in special facilities. Some experts maintain that even the nuclear power plant itself will eventually need to be dismantled or sealed tight because the building materials will themselves become radioactive and structurally flawed due to the prolonged exposure to radiation. The reason that there is such concern over these radioactive materials is that the radiation must not be allowed to escape into the environment and enter the food chain. When even trace amounts of radioactive materials are exposed to living cells, the cells can become defective and/or die. The release of radioactive materials into the environment can create long-term environmental problems.

In conclusion, it can be seen that both methods of generating electricity have environmental problems. Rather than wonder which method produces the least damage, it might be better to focus on conservation techniques that allow Canadians to use less electricity in the first place.

5. Students should be given full marks for keeping an accurate record of their progress on the spreadsheet.

6. Full marks should be given for thoughtful responses that are consistent with the data on the spreadsheet.

Final Test

Included here is the answer key to the final test and the student's copy of the final test which is designed for photocopying and possible faxing.

Note:

The answer key and student's copy of this final test should be kept secure by the teacher. Students should not have access to this test until it is assigned in a supervised situation. The answers should be stored securely and retained by the teacher at all times.

PHYSICS 20

FINAL TEST ANSWER KEY

Part A: Multiple Choice

1. A
2. B
3. C
4. D
5. C
6. B
7. D
8. C
9. A
10. B
11. D
12. B
13. C
14. C
15. B
16. A
17. D
18. C
19. A
20. B
21. A
22. B
23. C
24. D

Part B: Numerical Response

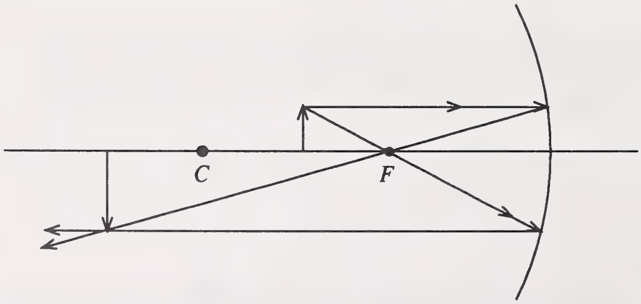
1. 84.6
2. – 9.61
3. 59
4. 8.20
5. 390
6. 59
7. 6.74
8. 8.37
9. 2.11
10. 38.3
11. 5.61
12. 9

Part C: Written Response

1. a.
   - The keys should land in your lap.
   - The keys will not fly behind you once tossed into the air because Newton's first law says that objects tend to maintain their velocity. The keys are also travelling at 85 km/h along with you and everything else in the bus.
   - The keys will accelerate downwards once in the air under the influence of the force of gravity. This downward acceleration will slow the upward motion of the keys until the keys stop and accelerate back down to your lap.

   b.
   - When the bus collides with the building, a force is exerted on the building. According to Newton's third law a reaction force is exerted back on the bus.
   - The reaction force acts in the opposite direction to the motion of the bus.
   - According to Newton's second law, unbalanced forces cause objects to accelerate in the direction of the force. The bus will accelerate in the opposite direction of its velocity.
   - The negative acceleration or decelleration will act to slow the bus down.

2. a.



b. Method 1: Using h_i & h_o

$h_o = 9.0\text{ mm}$

$h_i = 15.0\text{ mm}$

$m = ?$

$$m = \frac{h_i}{h_o} = \frac{15.0\text{ mm}}{9.0\text{ mm}} = 1.67 = 1.7$$

Method 2: Using d_i & d_o

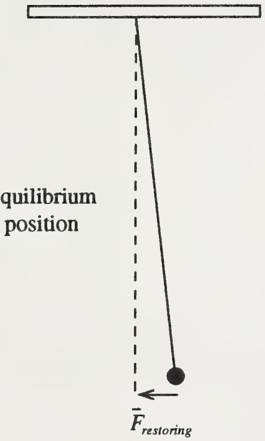
$d_o = 47.5\text{ mm}$

$d_i = 85.0\text{ mm}$

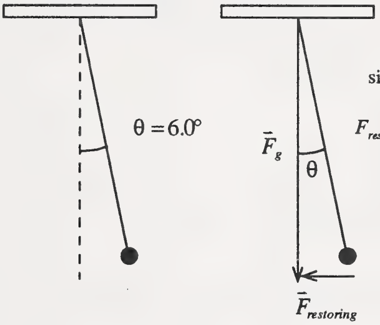
$m = ?$

$$m = \frac{-d_i}{d_o} = \frac{85.0\text{ mm}}{47.5\text{ mm}} = 1.79 = 1.8$$

3. a.



b.



$$\sin\theta = \frac{F_{restoring}}{F_g}$$

$$\begin{aligned} F_{restoring} &= \sin\theta\, F_g \\ &= \sin\theta\, m\, g \\ &= \sin(6.0°)(1.00\text{ kg})(9.80\text{ m/s}^2) \\ &= 1.0\text{ N} \end{aligned}$$

4. - At the top of the loop the rider will not fall if the centripetal force equals the gravitational force.

$$F_c = F_g$$

- substitution:

$$\frac{mv^2}{r} = mg$$

- rearrange:

$$\frac{v^2}{r} = g$$

$$v = \sqrt{rg}$$

- substitution of data:

$$v = \sqrt{(8.0\text{ m})(9.80\text{ m/s}^2)}$$

- solve

$$= 8.85\text{ m/s}$$
$$= 8.9\text{ m/s}$$

5. Half-life is the time for the activity of the sample to become half as much. Therefore, sample the data on the graph and average the values to determine the best value.

Change in Activity (counts/s)	**Time (s)**
200 to 100	160 – 67 = 93
160 to 80	193 – 93 = 100
120 to 60	237 – 133 = 104
100 to 50	262 – 160 = 102
60 to 30	335 – 237 = 98
50 to 25	360 – 262 = 98
40 to 20	400 – 296 = 104

$$\text{Average} = \frac{699\text{ s}}{7} = 99.8\text{ s} = 1.0 \times 10^{2}\text{ s}$$

Key:

- Correctly sampling two points and correctly determining a half-life.
- Correctly sampling and determining more than one half-life.
- Correctly using an averaging technique.
- Obtaining an answer of 100 s ± 5 s.

PHYSICS 20

FINAL TEST

GENERAL INSTRUCTIONS

YOU HAVE **TWO AND ONE-HALF** HOURS TO COMPLETE THIS TEST. Work through the entire test answering the questions you are sure you know. You will then be able to concentrate on the questions of which you are not quite sure.

TOTAL MARKS: 60

PART A: Multiple Choice	24 marks
PART B: Numerical Response	12 marks
PART C: Written Response	24 marks

A physics data sheet is provided for your reference. You are expected to provide your own scientific calculator.

PART A: MULTIPLE CHOICE

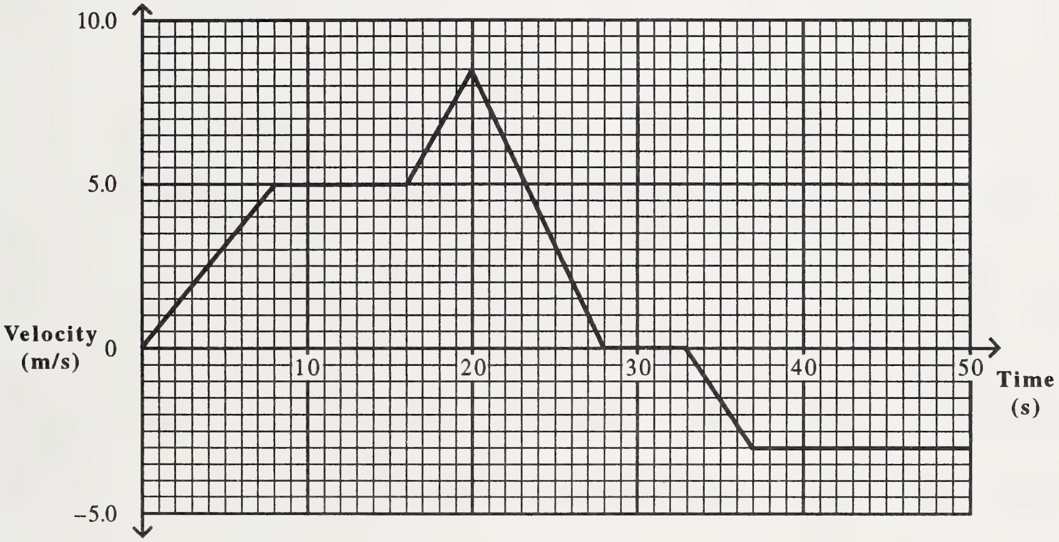
All multiple-choice questions must be answered on the Part A Response Page included in your test.

Read each question carefully and decide which of the choices BEST completes the statement or answers the question. Locate the question number on the Response Page and fill in the space that corresponds to your choice.

Consider all numbers used in the questions to be the result of a measurement.

Use the following information to answer questions 1 to 4.

The following graph describes the motion of a boat.



1. What was the total time that the boat was stopped?

   A. 5 s

   B. 6 s

   C. 11 s

   D. 27 s

2. What is the displacement of the boat for the time interval $t = 33$ s to $t = 50$ s?

   A. – 51.0 m

   B. – 45.5 m

   C. – 42.0 m

   D. – 37.5 m

3. During what time interval did the acceleration have its greatest magnitude?

   A. $t = 0$ s to $t = 80$ s

   B. $t = 16$ s to $t = 20$ s

   C. $t = 20$ s to $t = 28$ s

   D. $t = 33$ s to $t = 36$ s

4. During what time(s) did the boat change its direction of travel?

   A. $t = 8.0$ s, $t = 16.0$ s, $t = 20$ s, $t = 28$ s, $t = 33$ s, $t = 36$ s

   B. $t = 20$ s, $t = 33$ s

   C. $t = 20$ s

   D. $t = 33$ s

5. Which of the following is a list of quantities which are all vectors?

   A. velocity, force, momentum, time

   B. acceleration, momentum, mass, force

   C. acceleration, velocity, momentum, displacement

   D. time, mass, speed, distance

6. A force of 150 N directed at an angle of 20° above the horizontal is used to pull a wagon loaded with groceries a horizontal distance of 1.2×10^{2} m. The work done by the person pulling the wagon is

   A. 1.8×10^{4} J

   B. 1.7×10^{4} J

   C. 6.2×10^{3} J

   D. 1.4×10^{2} J

7. Snowflakes can be observed to fall through a distance of 2.0 m with nearly constant speed. Snowballs can be observed to accelerate when they fall through the same distance. Which of the following factors best explains the differences in these two motions?

   A. the greater mass of the snowball

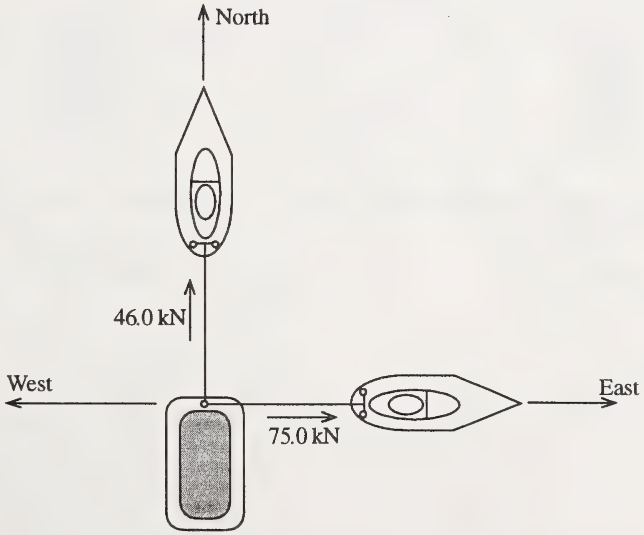
   B. the greater kinetic energy of the snowball

   C. the lower momentum of the snowflake

   D. the lower terminal velocity of the snowflake

Use the following information to answer questions 8 and 9.

A tugboat pulls due east on a barge with a force of 75.0 kN, while another tugboat pulls north with a force of 46.0 kN.



8. What is the magnitude of the net force on the barge?

A. 7741 kN

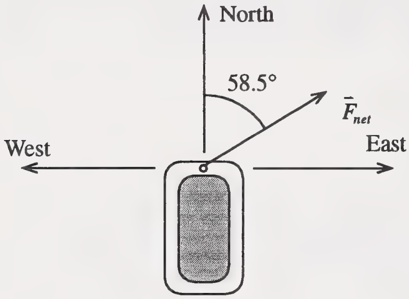
B. 121 kN

C. 88.0 kN

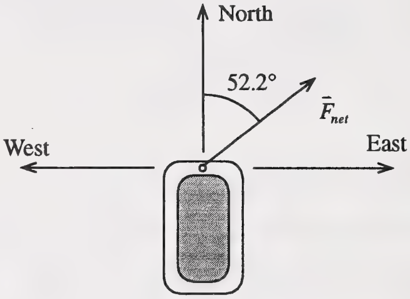
D. 29.0 kN

9. Which diagram best represents the direction of the net force on the barge?

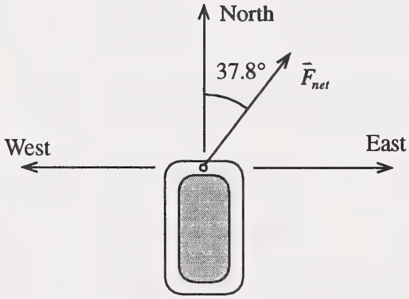
A.



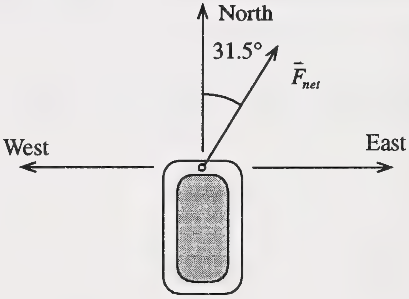
B.



C.



D.



10. The earth orbits the sun with an average radius of 1.50×10^{11} m and with a period of 3.156×10^{7} s. Using these values, the mass of the sun would be

A. 4.22×10^{26} kg

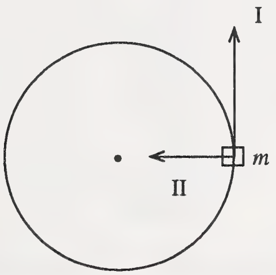
B. 2.01×10^{30} kg

C. 6.33×10^{37} kg

D. 1.50×10^{40} kg

Use the following information to answer question 11.

The following diagram shows a mass, m, undergoing circular motion. The vectors I and II represent quantities that describe the circular motion.



11. Which of the following best describes a possible identity for vectors I and II?

    A. Vector I is centripetal acceleration and vector II is velocity.

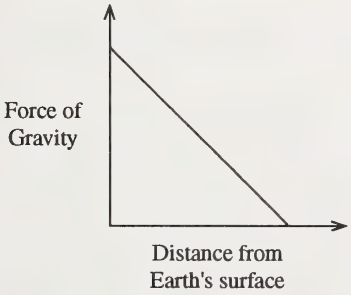
    B. Vector I is centripetal acceleration and vector II is centripetal force.

    C. Vector I is centripetal force and vector II is velocity.

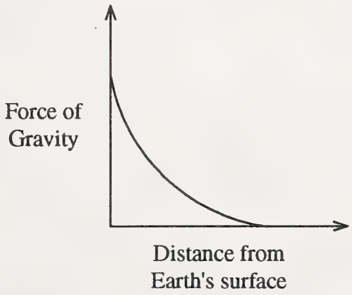
    D. Vector I is velocity and vector II is centripetal force.

12. A rocket is launched from the surface of the earth into space. Which of the following graphs best shows how the earth's force of gravity on the rocket would change as the rocket travels away from the earth?

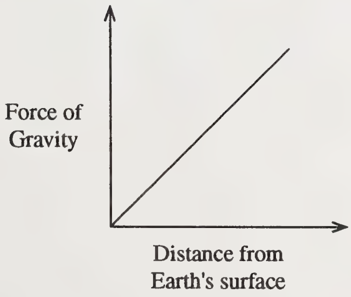
A.



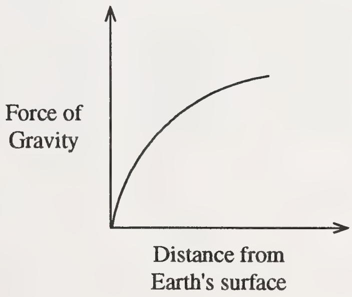
B.



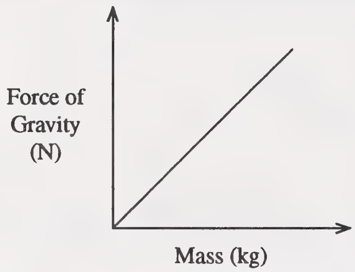
C.



D.



Use the following information to answer question 13.



This graph shows how the force of gravity on any planet varies with the mass of the object that it is acting upon.

13. The slope of this graph always represents

A. the universal gravitational constant

B. the mass of the earth

C. the gravitational field

D. 9.80 m/s^2

14. Venus has a mass of 4.88×10^{24} kg and an average radius of 6.07×10^{6} m. If an astronaut weighed 816 N on earth, the weight of the astronaut on Venus would be

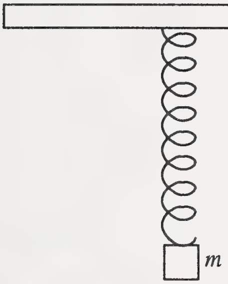
A. 7.21×10^{3} N

B. 9.53×10^{2} N

C. 7.36×10^{2} N

D. 8.33×10^{1} N

Use the following diagram to answer question 15.



The mass, *m*, can vibrate on this spring with simple harmonic motion.

15. If the mass on the spring was increased, you would expect that

    A. the frequency of vibration would increase

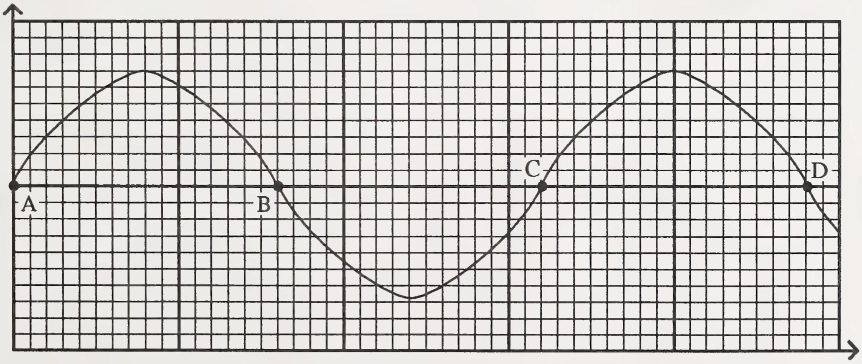
    B. the frequency of vibration would decrease

    C. the period of vibration would decrease

    D. the frequency and period would remain unchanged

Use the following information to answer question 16.

The following diagram shows a wave. Each small square represents 10 cm.



16. The wave shown above can travel from point A to point D in 3.0 s. The frequency of the wave is

A. 0.50 Hz

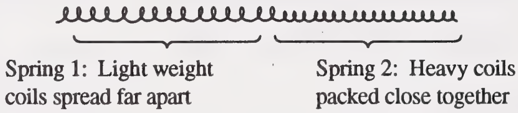
B. 1.0 Hz

C. 2.0 Hz

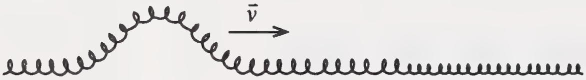
D. 2.3 Hz

Use the following diagram to answer question 17.

The diagram shows two springs attached.

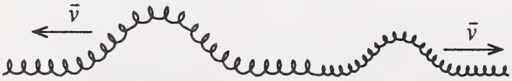

Spring 1: Light weight coils spread far apart
Spring 2: Heavy coils packed close together

A pulse is shown travelling in spring 1, towards spring 2.

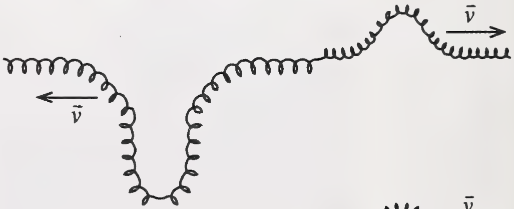


17. Which of the following diagrams best shows the condition of both springs after the pulse encountered the boundary?

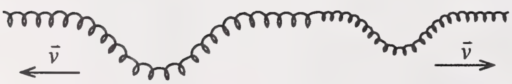
A.



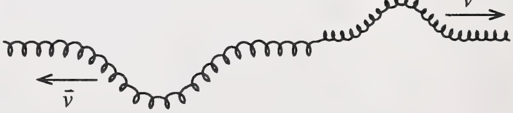
B.



C.



D.



18. When light passes into and out of a fish tank, changes occur in

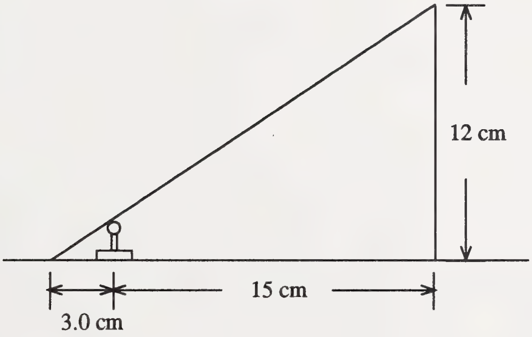
A. wavelength only

B. frequency and speed

C. wavelength and speed

D. frequency, wavelength, and speed

Use the following information to answer question 19.



A light source placed 3.0 cm behind an object is used to project a shadow of the object onto a screen placed 15 cm from the object.

19. If the shadow has a height of 12 cm, the height of the object will be

A. 2.0 cm

B. 2.4 cm

C. 3.8 cm

D. 4.5 cm

20. Light that enters glass at an oblique angle

A. slows down and bends away from the normal

B. slows down and bends toward the normal

C. speeds up and bends away from the normal

D. speeds up and bends toward the normal

21. A photocopier uses a lens that creates a real image of the original piece of paper to be copied. A letter that is to be magnified 1.25 times is placed on the glass of the machine, which is 40.0 cm from the lens. The focal length of the lens is

A. 22.2 cm

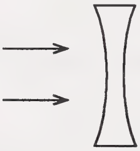
B. 45.0 cm

C. 50.0 cm

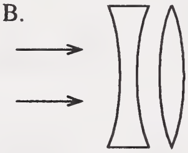
D. 200 cm

22. For which lens configuration could the emerging rays be parallel?

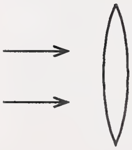
A.



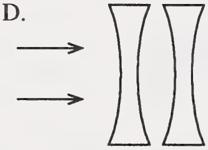
B.



C.



D.



23. Young's double-slit experiment provided evidence that light

A. can be dispersed

B. can be polarized

C. has wave-like properties

D. has particle-like properties

24. An interference pattern is produced by passing red light through a double slit. If light of shorter wavelength is used instead of red, the fringes of the interference pattern will

A. disappear

B. remain the same

C. move farther apart

D. move closer together

PART A: RESPONSE PAGE

1. ________
2. ________
3. ________
4. ________
5. ________
6. ________
7. ________
8. ________
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20. ________
21. ________
22. ________
23. ________
24. ________

Name of Student ____________________ Student I.D. # ____________________

Name of School ____________________ Date ____________________

PART B: NUMERICAL RESPONSE

Answer each of the following questions using the space available on the Part B Response Page included in your test.

Consider all numbers used in the questions to be the result of a measurement.

Only the final answer is required on the Response Page.

1. A family leaves Medicine Hat at 8:00 a.m. to travel 931 km to Fort McMurray. They have planned to stop and take only 1.0 h for lunch and 1.0 h for supper. The average speed that the family must maintain to arrive in Fort McMurray at 9:00 p.m. that day is ________ km/h.
(Round and record your answer to three digits.)

2. A race car travelling at + 110 km/h brakes and comes to a stop in 48.6 m. To do this, the car must accelerate uniformly at ________ m/s.
(Round and record your answer to three digits.)

3. A sled with a mass of 40 kg is pulled along snow-covered flat ground. The coefficient of sliding friction is 0.15. The horizontal force that must be applied to keep the sled moving at a constant velocity is ________ N.
(Round and record your answer to two digits.)

4. A baseball with a mass of 0.155 kg travels at + 25.0 m/s towards the batter. The bat contacts the ball for 9.45×10^{-4} s, giving the ball a velocity of – 25.0 m/s as it leaves the bat. The average force that the bat exerts on the ball is $b \times 10^{-w}$ N.

   The value of b is ________.
   (Round and record your answer to three digits.)

5. An arrow is shot horizontally at 78.0 m/s from the top of a building that is 122.5 m high. The arrow will land ________ m from the base of the building.
(Round and record your answer to three digits.)

6. A child with a mass of 42 kg is hanging on to the outside of a merry-go-round that has a diameter of 4.0 m. The merry-go-round makes 8.0 revolutions in 60.0 s. The minimum force that the child must supply to stay on the ride is ________ N.
(Round and record your answer to two digits.)

7. The gravitational force between a 1.74×10^{4}-kg spacecraft and a 4.72×10^{12}-kg asteroid that are separated by 2.85×10^{6} m is $b \times 10^{-w}$ N.

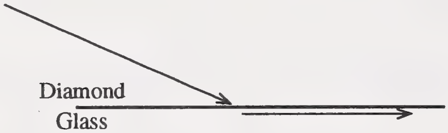
   The value of b is ________.
   (Round and record your answer to three digits.)

8. The speed of sound in air at room temperature is 343 m/s. If a pipe that is closed at one end is found to resonate for sounds with a frequency of 1024 Hz, the minimum length of the pipe is ________ cm.
(Round and record your answer to three digits.)

9. A beam of red light has a wavelength of 6.328×10^{-7} m while travelling in a vacuum. The period of this red light is $b \times 10^{-w}$ s.

The value of b is ________.
(Round and record your answer to three digits.)

10. A ray of light travels from diamond ($n = 2.42$) into glass ($n = 1.50$) as shown in the following diagram:



The critical angle for this case should be ________ degrees.
(Round and record your answer to three digits.)

11. Monochromatic light passes through a diffraction grating with 8000 lines per metre. The pattern was produced on a screen that is 1.65 m away as the second order antinode spaced 14.8 mm from the central antinode. The wavelength of the light is $b \times 10^{-w}$ m. The value of b is ________.
(Round and record your answer to three digits.)

12. It is estimated that the sun produces 4×10^{26} W due to the process of fusion. The amount of mass that must be converted into energy each second would be $b \times 10^{w}$ kg. The value of the exponent **w** is ________.

PART B: RESPONSE PAGE

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

6. ____________________

7. ____________________

8. ____________________

9. ____________________

10. ____________________

11. ____________________

12. ____________________

Name of Student ____________________ Student I.D. # ____________________

Name of School ____________________ Date ____________________

PART C: WRITTEN RESPONSE

Answer each of the following questions using the space available on the Part C Response Pages included in your test.

For full marks, your answers must show all pertinent explanations, calculations, and equations.

Your answers should be presented in a well-organized manner using complete sentences for a written response, and correct units and significant digits for a numerical response.

Consider all numbers used in the questions to be the result of a measurement.

⑦ 1. Imagine that you are riding on a bus.

a. You are sitting in a seat while the bus travels uniformly at 85 km/h. Predict where your keys would land if you tossed them straight up into the air from your lap. Assume that your keys do not touch anything while in the air. Support your prediction using principles from the Physics 20 course.

b. The driver of the bus becomes distracted while backing up at 12 km/h. The bus collides with the corner of a large building. Predict what would happen to the motion of the bus in the first few seconds of the collision. Support your prediction using principles from the course that would relate the collision with the building to the motion of the bus.

⑤ 2. a. Use a ray diagram to locate the image of the arrow reflected from the concave mirror shown on the response page.

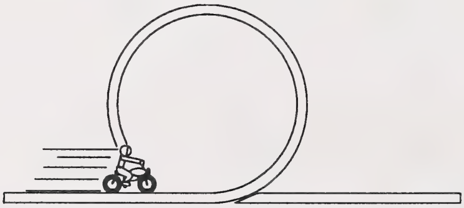
b. Use a millimetre ruler to make the necessary measurements to determine the magnification for the diagram. Use your measurements to calculate the magnification.

④ 3. A pendulum is formed by suspending a 1.00-kg mass from the end of a very light thread. The pendulum is pulled sideways so that it makes an angle of 6.0° with the vertical.

a. Draw a diagram of the pendulum. Label the equilibrium position and the direction of the restoring force.

b. Calculate the restoring force acting on the pendulum bob.

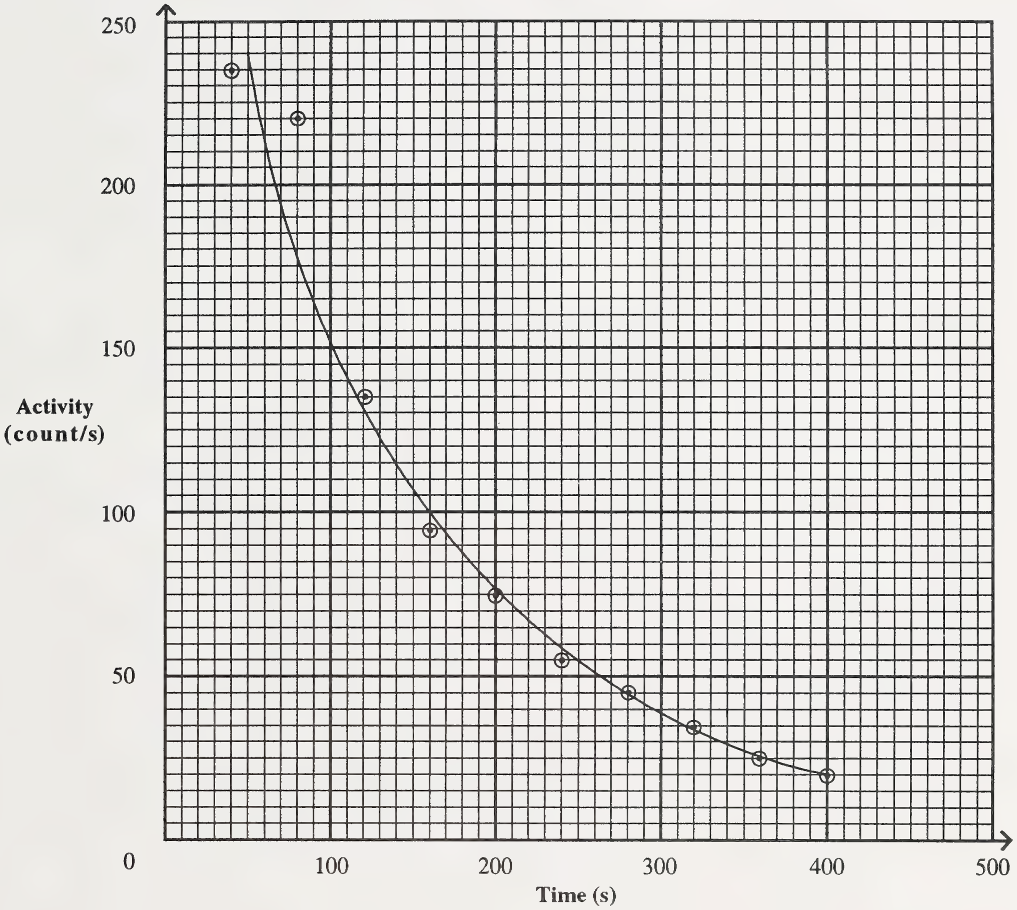
④ 4. A stunt rider is able to drive a 138-kg motorcycle along a circular, vertical loop with a diameter of 16.0 m. The mass of the rider is 78.5 kg. Determine the minimum speed that the rider must maintain so that he will be able to make a complete loop without falling from the top. Note that under these conditions, when the driver is at the top of the loop, the effects of gravity equal the effects of circular motion, making the driver feel weightless.



④

5. An experiment was done to carefully measure the radioactivity of a sample over a period of time. The results of this experiment are shown on the graph that follows.

Activity Time Graph for a Radioactive Sample



Use the data presented on the graph to determine the best estimate of the half-life of this sample.

PART C: RESPONSE PAGE

1. a. ______

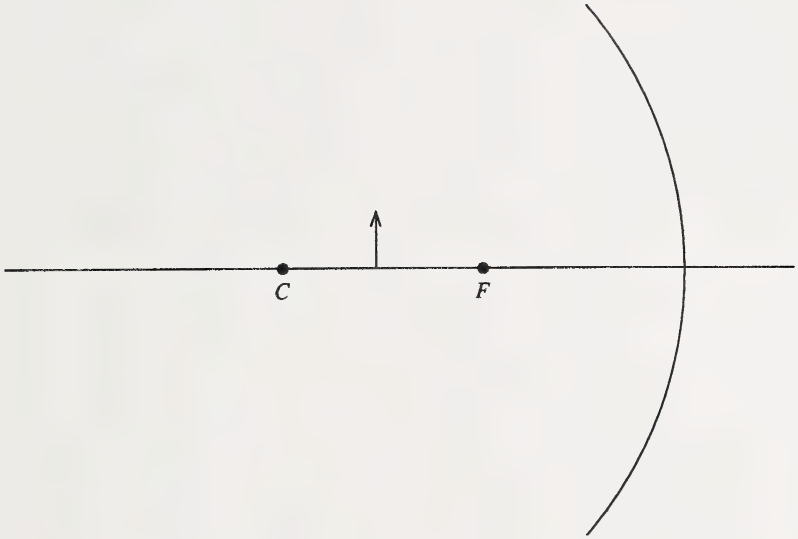
b. ______

Name of Student ______ Student I.D. # ______

Name of School ______ Date ______

PART C: RESPONSE PAGE

2. a.



b.

Name of Student	____________	Student I.D. #	____________
Name of School	____________	Date	____________

PART C: RESPONSE PAGE

3. a.

b.

Name of Student ______________________ Student I.D. # ______________________

Name of School ______________________ Date ______________________

PART C: RESPONSE PAGE

4.

Name of Student ______________	Student I.D. # ______________
Name of School ______________	Date ______________

PART C: RESPONSE PAGE

5.

Name of Student ____________________	Student I.D. # ____________________
Name of School ____________________	Date ____________________

PHYSICS 20/30 EQUATIONS

Trigonometry and Vectors

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} \text{ or } \sin\theta = \frac{y}{r}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} \text{ or } \cos\theta = \frac{x}{r}$$

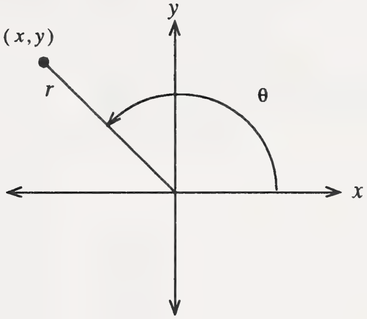
$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} \text{ or } \tan\theta = \frac{y}{x}$$

$$C = \sqrt{A^2 + B^2}$$

$$R_x = R\cos\theta$$

$$R_y = R\sin\theta$$

$$\tan\theta = \frac{R_y}{R_x}$$



Kinematics

$$\vec{v}_{ave} = \frac{\vec{d}}{t}$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

$$v_f^{\,2} = v_i^{\,2} + 2ad$$

Dynamics

$$\vec{F} = m\vec{a}$$

$$\vec{F}t = m\Delta\vec{v}$$

$$\vec{F}_g = m\vec{g}$$

$$F_f = \mu F_n$$

$$\vec{F}_s = -k\vec{x}$$

$$F_g = \frac{Gm_1m_2}{r^2}$$

$$g = \frac{Gm_1}{r^2}$$

$$F_c = \frac{mv^2}{r}$$

$$F_c = \frac{4\pi^2 m\, r}{T^2}$$

Momentum and Energy

$\vec{p} = m\vec{v}$

$W = Fd$

$W = Fd\cos\theta$

$P = \frac{W}{t}$

$E_k = \frac{1}{2}mv^2$

$E_p = mgh$

$E_p = \frac{1}{2}kx^2$

Simple Harmonic Motion, Waves, and Light

$T = 2\pi\sqrt{\frac{l}{g}}$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = \frac{1}{f}$

$v = f\lambda$

$\frac{\lambda_1}{2} = l; \frac{\lambda_1}{4} = l$

$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$

$\lambda = \frac{xd}{nl}$

$\lambda = \frac{d\sin\theta}{n}$

$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

Relativity and Quantum Physics

$E = mc^2$

TEACHER QUESTIONNAIRE FOR PHYSICS 20

This is a course designed in a new distance-learning format, so we are interested in your responses. Your constructive comments will be greatly appreciated so that a future revision may incorporate any necessary improvements.

Teacher's Name ______________________ Area of Expertise ______________________

School Name ______________________ Date ______________________

Design

1. The modules follow a definite systematic design. Did you find it easy to follow?

   ☐ Yes ☐ No If no, explain.

   ____

   ____

2. Did your observations reveal that the students found the design easy to follow?

   ☐ Yes ☐ No If no, explain.

   ____

   ____

3. Did you find the Learning Facilitator's Manual helpful?

   ☐ Yes ☐ No If no, explain.

   ____

   ____

4. Part of the design involves stating the objectives in student terms. Do you feel this helped the students understand what they were going to learn?

   ☐ Yes ☐ No If no, explain.

   ____

   ____

5. The Learning Facilitator's Manual contains Assignment answers and a sample test. Did you find these helpful?

☐ Yes ☐ No If no, explain.

6. Did the Follow-up Activities prove to be helpful?

☐ Yes ☐ No If no, explain.

7. Were students motivated to try these Follow-up Activities?

☐ Yes ☐ No If no, give details.

8. Suggestions for computer and video activities are included in the course. Were your students able to use these activities?

☐ Yes ☐ No Comment on the lines below.

9. Were the assignments appropriate?

☐ Yes ☐ No If no, give details.

Teacher's Name ______

Name of School ______ Date ______

10. Did you fax assignments?

☐ Yes ☐ No

11. If you did fax, did you get satisfactory results from using this procedure?

☐ Yes ☐ No If no, give details.

____

____

Instruction

1. Did you find the instruction clear?

☐ Yes ☐ No If no, give details.

____

____

2. Did your observations reveal that the students found the instruction interesting?

☐ Yes ☐ No If no, give details.

____

____

3. Did you find the instruction adequate?

☐ Yes ☐ No If no, give details.

____

____

4. Was the reading level appropriate?

☐ Yes ☐ No If no, give details.

____

____

Teacher's Name ______________________________

Name of School ________________ Date ________________

5. Was the work load adequate?

☐ Yes ☐ No If no, give details.

6. Was the content accurate and current?

☐ Yes ☐ No If no, give details.

7. Did the content flow consistently and logically?

☐ Yes ☐ No If no, give details.

8. Was the transition between booklets smooth?

☐ Yes ☐ No If no, give details.

9. Was the transition between print and media smooth?

☐ Yes ☐ No If no, give details.

Teacher's Name ______________________

Name of School ______________ Date ______________

Additional Comments

Thanks for taking the time to complete this survey. Your feedback is important to us.

Fax Number: 674-6686

Instructional Design and Development Unit
Alberta Distance Learning Centre
Box 4000
Barrhead, Alberta
T0G 2P0

Note: Please ensure that each of your students has completed and forwarded a copy of the Course Survey.

Teacher's Name ____________________

Name of School ____________________ Date ____________________

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Physics 20

Learning Facilitator's
Manual

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